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COMPRESSED AIR AT HIGH ALTITUDES

WHY MORE AIR IS REQUIRED—SIMPLE METHODS FOR CALCULATING THE POWER NEEDED FOR COMPRESSING.

BY S B. REDFIELD.

Most users of compressed air are aware of the fact that at high altitudes, such as a mine located in mountainous country, a greater quantity of compressed air at a given pressure is required to do a given amount of work, such as rock drilling, than would be required to do the same amount of work at sea level.

Furthermore, the catalogues of the various makers of air compressors give lists of special compressors with extra large cylinder diameters, for altitude work. These tables show that the higher the altitude, the greater the volume of air that may be compressed to a given gage pressure with an equal amount of work. Thus it appears that while more air is required to do a given amount of work at a high altitude, more air may be compressed to a given pressure at that altitude with a given amount of power, and the question naturally arises as to whether or not these two effects neutralize each other with the result that the total actual amount of power required to do work at a high altitude may remain the same as at sea leved. In reality these two effects do not neutralize each other, and in studying this question, the diagrams presented will serve to clearly show the actual conditions.

THE REASON WHY.

Before arriving at final results, a study of the "reason why" will be of interest. In the first place, why does it take more air at a high altitude to do a given amount of work? The first and most obvious answer to this question is that the air is "rarer" at a high altitude. This is a good, general answer when air-operated machinery is viewed as a heat engine, but it does not give a sufficient explanation for most people.

Work is the product of a force through a distance. Suppose the working medium is compressed air, and, naturally, that it exerts its pressure against the face of a piston. Then the product of the air pressure by the area of the piston will give the "force," and the travel of the piston will give the "distance," resulting in work accomplished. Of course, the air must have a definite pressure, the piston a definite area and the travel must be defined in order to do a definite, measured amount of work. The actual air pressure which does the work is the difference between the absolute pressure on one side of the piston, and the atmospheric pressure on the other side; in other words, it is the gage pressure. Now it is the atmospheric pressure which changes at high altitudes, and it is this that makes all the difference in air required and power developed.

As it is the gage pressure which actually does the work, a given gage pressure will exert the same force on an equal piston area at any altitude. For instance, 100 pounds gage pressure per square inch acting on a piston area of, say, 100 square inches, will exert a total force of 10,000 pounds, no matter what the altitude or atmospheric pressure may be.

This may be viewed in another way. At sea level 100 pounds gage pressure will be 114.7 pounds per square inch absolute, and acting on 100 square inches will exert 11,470 pounds pressure on one side of the piston,

while the atmosphere will exert 14.7 pounds per square inch absolute on the other side, or 1,470 pounds pressure. The resultant force is 11,470 — 1,470 = 10,000 pounds urging the piston on. If the altitude were 8,000 feet above sea level and the atmospheric pressure were 10.9 pounds absolute, 100 pounds gage pressure would be 110.9 pounds absolute, and acting on 100 square inches of piston area the total force exerted would be 11,090 pounds, while the atmosphere on the other side would exert a pressure of 10.9 pounds per square inch, or 1,090 pounds upon the back of the picton. The esultant force is 11,090 — 1,090 = 10,000 pounds tending to move the piston, as before.

From this it is seen that the change in atmospheric pressure due to altitude has no effect whatever on the net force exerted upon a given piston area by a given gage pressure. Then why is more air required to do work at a high altitude? The cause lies in the volume of compressed air The quantity of compressed air required to fill a given space depends upon the pressure of the air, and it is the absolute pressure to which it is directly proportional.

Again, let us assume 100 pounds gage pressure and 100 square inches of piston area and let the distance moved through be 1 foot. Then no matter what the altitude, the total force exerted will be 10,000 pounds, as already shown, and moving through 1 foot of distance the work performed will be 10,000 foot-pounds. The quantity of free air required to do this work nonexpansively will be the volume of the cylinder multiplied by the absolute ratio of compression of the air, or the number of times it has been compressed. At sea level, the ratio of compression would, in this case, be 114.7 ÷ 14.7 = 7.8. The volume of the cylinder we are considering is 1,200 cubic inches, or 0.694 cubic foot, so the total quantity of free atmospheric air that would be used at sea level would be 0.694×7.8=5.42 cubic feet.

If this had been done at, say, 8,000 feet altitude, and the atmospheric pressure were 10.9, the ratio of compression would have been 110.9 ÷ 10.9 = 10.16. Then the total quantity of free atmospheric air that would have been used at 8,000 feet altitude would be 0.694 × 10.16 = 7.05 cubic feet.

By this it is seen that while at sea level 5.42 cubic feet of free atmospheric air acting at 100 pounds gage pressure will do 10,000 foot-pounds of work, it will require 7.05 cubic feet of free air to do the same work acting on the same piston at 8,000 feet altitude. This is an increase of 30 per cent of free air or piston displacement of compressor required, and is, of course, based on nonexpansive operation, as is usually the case with air-operated machinery.

POWER REQUIRED TO COMPRESS THE AIR.

Now to look at the matter of the power required to compress this increased quantity of air at a high altitude. The formula for the power required to compress 100 cubic feet of free air per minute to any pressure is, for single-stage compression:

Indicated Horsepower=

$$1.51\ p_1\left(R^{0.29} - 1\right).$$

For compound compression the formula is:

Indicated Horsepower=

$$3.02\ p_1\left(R^{0.145} - 1\right).$$

In these formulas p^1 is the absolute initial pressure per square inch at the inlet to the compressor, usually that of the atmosphere, and R is the ratio of compression, or the absolute discharge pressure divided by the absolute initial pressure. This shows that the power required to compress a given cylinder volume of air to any pressure depends upon the initial or atmospheric pressure. As this factor appears in the formulas both outside the bracket, to the first power, and also in the ratio of compression raised to a fractional power, it is plain that the power required will not vary in a simple ratio with the intake or atmospheric pressure. As the quantity of air required to do a certain amount of work does vary directly with the ratio of compression, which is dependent upon the atmospheric pressure, it is clear that the one does not increase at the same rate at which the other decreases, and the net result of power required to do a certain amount of work by compressed air will vary with the atmospheric pressure and therefore with the altitude.

By figuring out the amount of air required and the amount of power required to compress this air, to do a given amount of work, at various altitudes, it will be found that the higher the altitude the more power it will take to do this work. Of course the pressure of the air has some bearing on the subject, but it is a fact that within the limits of usual pressures employed, the increase of power varies very little with the air pressure, at a given altitude.

The curves given in Fig. 1 show how the free air, or compressor-piston displacement, and the power required increase with the altitude. The increase is given in percentage of that required at sea leved. The curves of piston displacement increase are calculated with both 100 pounds and 80 pounds gage pressure at the drills, and the curves of power increase are calculated with 100 pounds gage pressure at the compressor, as a basis. It should be understood that this latter pair of curves does not show the change in power required to compress a given amount of air, but that it does show the increase of power required in the compressor to do a given amount of work in such a device as a rock drill, or other reciprocating machine, operated by compressed air without cutoff or expansion. The full-line power curve shows theoretical results, counting or using the air in the drill at exactly the same pressure as that of the compressor discharge, or in other words, without pipe-line pressure drop. The broken line is calculated on a basis of using the air in the drill at a pressure 20 pounds below that of the compressor.

From these power curves it appears that at 10,000 feet altitude, with no pressure drop, the power required is 15.2 per cent. more than at sea level, while if 20 pounds pipe-line pressure drop is allowed, the increase is about 14.1 per cent. At 5,000 feet altitude, these figures are 7.25 and 6.85 per cent., respectively. This statement is liable to raise a misunderstanding, for it seems to show that a pressure loss in the pipe line is an advantage, which is against common-sense reasoning.

As a matter of fact, the full-line and broken-line power curves in Fig. 1 should not be compared with each other, for any point on either curve is relative to other points on itself only. The actual power required at any altitude with 20 pounds pressure drop in the pipe line is, of course more than that required without any pressure drop, but at a higher altitude the *increase* of power required, due to that altitude, is less than when there is none. This is easy to see when it is remembered that a given measured increase of power would be a smaller percentage of the larger power, and it is, of course, advisable to have as little pressure loss in the pipe line as is possible. The

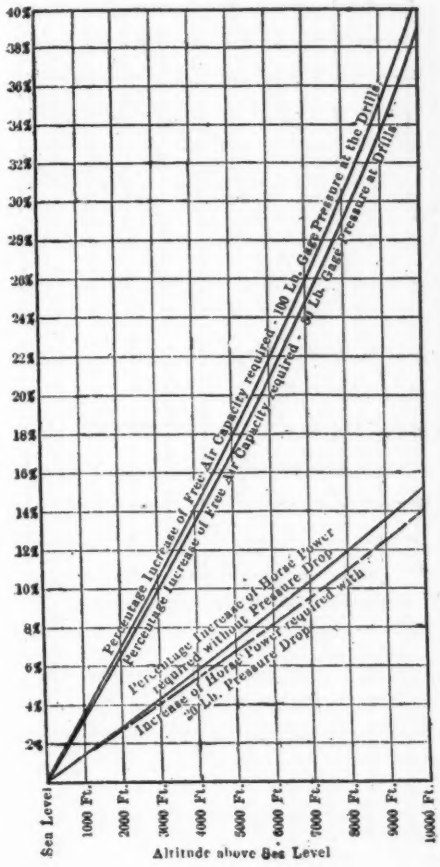


FIG. 1

curves are figured on compound compression because this is the most usual, especially for altitude work, where the ratio of compression increases considerably, giving rise to high cylinder temperatures.

The most useful feature of this discussion will be found in Figs. 2, 3, and 4, where curves are plotted to show how the indicated horsepower required to compress 100 cubic feet pis-

ton displacement of free air per minute varies with the pressure at different altitudes, and also how it varies with the altitude at different pressures. These two sets of curves viewed together reveal the rather curious fact

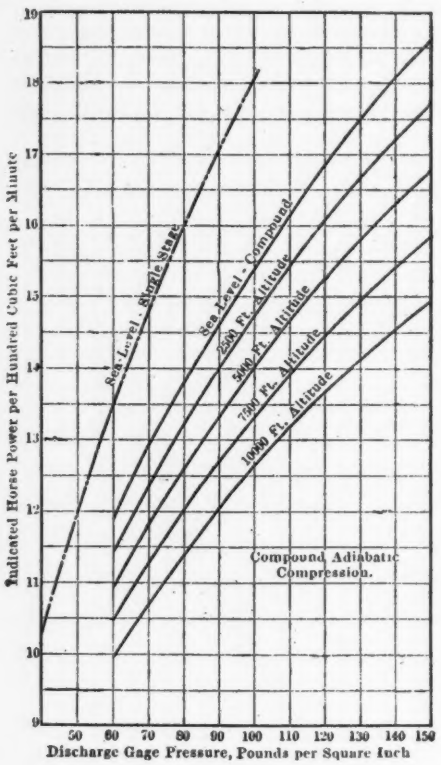

Indicated Horse Power per Hundred Cubic Feet per Minute
Discharge Gage Pressure, Pounds per Square Inch
Sea Level - Single stage
Sea Level - Compound
2500 Ft. Altitude
5000 Ft. Altitude
7500 Ft. Altitude
10000 Ft. Altitude
Compound Adiabatic Compression.

FIG. 2

that although the indicated horsepower at a given altitude varies with the pressure in a curved line, the variation with the altitude at a given pressure looks like a straight line (Fig. 4).

These lines are, however, not straight, for when the calculations are carried through a wider range of intake pressure variation, it is found that the lines begin to curve to a very marked degree. This is shown in the two lower curves of Fig. 6. In this figure, horizontal distances represent absolute initial pressure at the compressor intake, and the marking on the various curves clearly indicates what they each represent. All the calculations illustrated in Fig. 6 are based on 100 pounds gage, compressor-discharge pressure, assuming the atmospheric, or initial-intake pressure, to vary from zero or absolute vacuum, to a maximum of 300 pounds absolute.

These curves, then, may be taken to show what would occur in caisson work, where drills are operated in an atmosphere denser than that existing outside, assuming that the drill compressor draws its air supply from the caisson itself. As before stated, the working pressure is 100 pounds gage at all times; that is a pressure gage placed in the dense atmosphere and connected to the compressor discharge would always read 100 pounds no matter what the absolute pressure of the atmosphere in

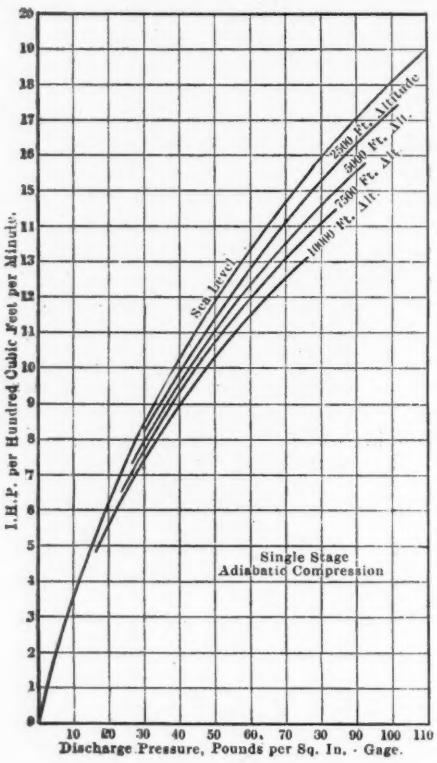

I.H.P. per Hundred Cubic Feet per Minute
Discharge Pressure, Pounds per Sq. In. - Gage.
Sea Level
2500 Ft. Altitude
5000 Ft. Alt.
7500 Ft. Alt.
10000 Ft. Alt.
Single Stage Adiabatic Compression

FIG. 3

the caisson. For instance, when the absolute pressure of the caisson atmosphere is 20 pounds, the absolute compressor discharge is 120; when it is 50 pounds the absolute compressor-discharge pressure is 150 pounds, and when the atmosphere is at 200 pounds, the discharge pressure is 300 pounds absolute. Of course, in practice, caissons are seldom or ever operated with an atmosphere above 40 pounds gage, or 55 pounds absolute, so, for

actual conditions, the curves in Fig. 4 could have been limited between an initial pressure of 10 pounds absolute, for 10,000 feet altitude work and 55 pounds absolute for the heaviest caisson work. However, the calculations were extended from zero to 300 pounds absolute-initial pressure simply to show the trend of the curves.

It will be seen that the curves of the in-

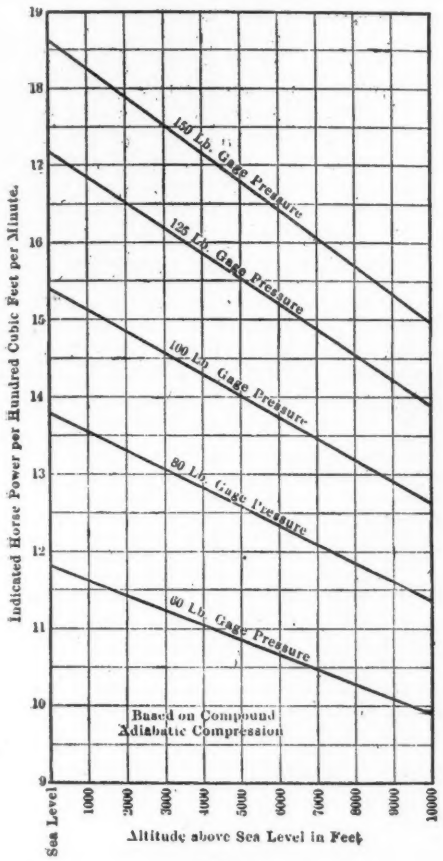


FIG. 4

dicated horsepower per 100 cubic feet compressor displacement for single-stage and for compound compression both start at zero indicated horsepower, with zero atmosphere, or absolute vacuum, and as the atmospheric pressure increases they diverge considerably, well showing the saving by compound compression. However, as the atmospheric pressure increases and the ratio of compression becomes less and less (at 14.7 pounds absolute-initial pressure the ratio of compression is 7.8 and at 300 pounds absolute-initial pressure it is only 1.5, assuming always 100 pounds gage discharge pressure), the two lines again come nearer and nearer each other, until they meet at infinity.

Above these two indicated horsepower factor curves is another curve showing the compressor displacement required per 100 cubic feet of drill-cylinder displacement, under what might be termed extended caisson conditions. Above this, again, are curves showing the total

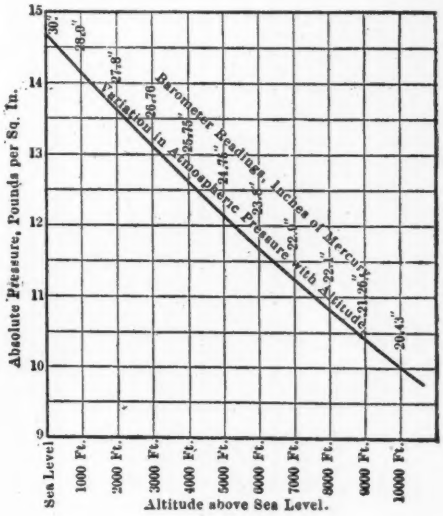


FIG. 5

indicated horsepower required in the compressor per 100 cubic feet of drill-cylinder displacement per minute. This drill displacement may be taken as the measure of the actual work done by the air in the drill, because the working pressure is assumed to always remain at 100 pounds gage. All these lines then show the various requirements of air and power to do the same amount of work in the drills, as the caisson atmosphere is varied from vacuum to 300 pounds absolute.

Assuming single-stage compression, it appears that while the total compressor indicated horsepower per 100 cubic feet of drill displacement per minute is 142 when the atmosphere is at 14.7 pounds absolute, or normal, the compressor power required is only 82 indicated horsepower, or 58 per cent. of this, when the caisson atmosphere is 55 pounds absolute, or 40 pounds gage. Comparing the power required at 55 pounds absolute caisson pressure

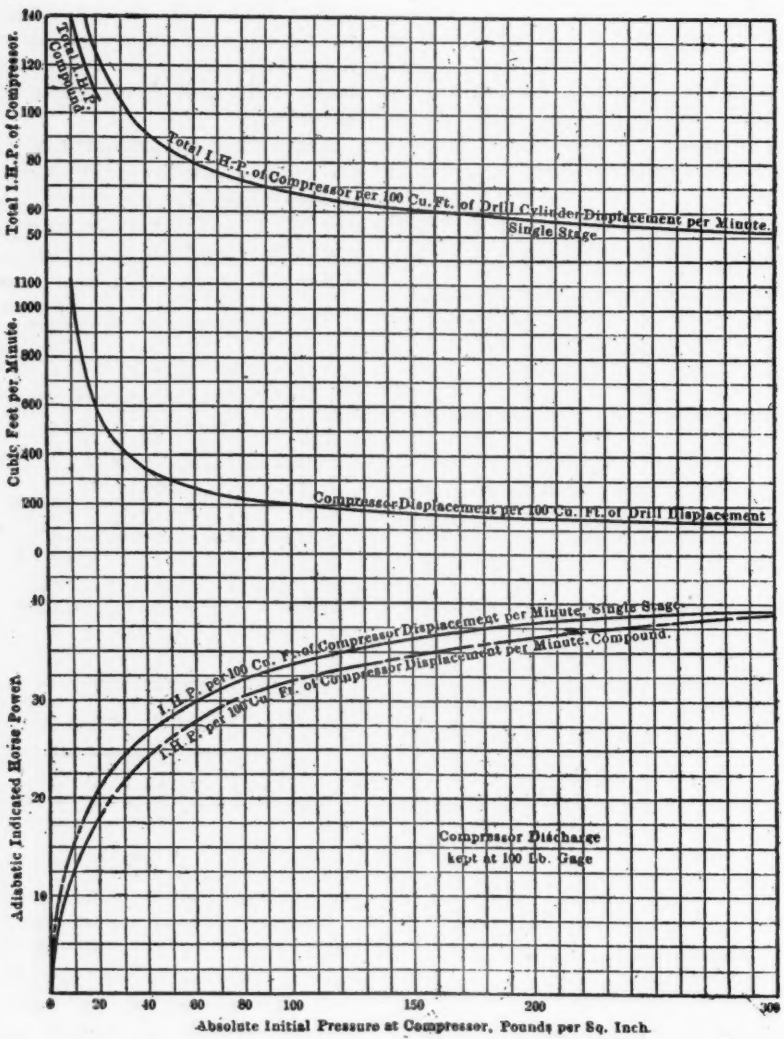

Total I.H.P. of Compressor.
Total I.H.P. Compound.
Total I.H.P. of Compressor per 100 Cu. Ft. of Drill Cylinder Displacement per Minute. Single Stage.
Cubic Feet per Minute.
Compressor Displacement per 100 Cu. Ft. of Drill Displacement
Adiabatic Indicated Horse Power.
I.H.P. per 100 Cu. Ft. of Compressor Displacement per Minute, Single Stage.
I.H.P. per 100 Cu. Ft. of Compressor Displacement per Minute, Compound.
Compressor Discharge kept at 100 Lb. Gage
Absolute Initial Pressure at Compressor, Pounds per Sq. Inch.

FIG. 6.

by single-stage compression with compound compression at 14.7 pounds absolute-atmospheric pressure, we have 120 for the latter, and 82 for the former, and 82 is 68 per cent. of 120. Compound compression would not pay for an atmosphere above 20 pounds absolute, with 100 pounds gage working pressure, because the ratio of compression becomes too small.

As a matter df fact, in actual caisson work, the compressors driving the drills usually draw their air supply from the natural outside atmosphere and thus add their output, through the drills, to the air being pumped directly into the caisson. It would at first appear that they would save considerable power by drawing the air for the drills from that in the caisson, thus using it over and over again, but of course just exactly the amount of air used by the drills would have to be pumped into the caisson by the low-pressure compressors, to keep out the water, so nothing would be saved by this means after all.

Some attempts have been made to apply this high intake-pressure method of operation to the driving of drills and pumps, and much

calculation and writing has been done on the subject, which is known as the "dense-air system." Its theoretical savings are indeed attractive, but it is a difficult system to govern, not being flexible, and the troubles with leakage in the double pipe lines, and many other difficulties, have prevented its extensive adoption. There are, however, some large examples of its use in the South African mines, at the present time.

The curves given in Figs. 2, 3 and 4 will be found useful for figuring the power required to drive a compressor of a given size at any altitude from sea level to 10,000 feet elevation. The figures give theoretical adiabatic indicated horsepowers developed in the compressing cylinders, per 100 cubic feet of piston displacement per minute, and to these should be added about 12 per cent. for a steam machine and 20 per cent. for belt driving, to allow for mechanical efficiency of the moving parts of the machine, belt, etc.

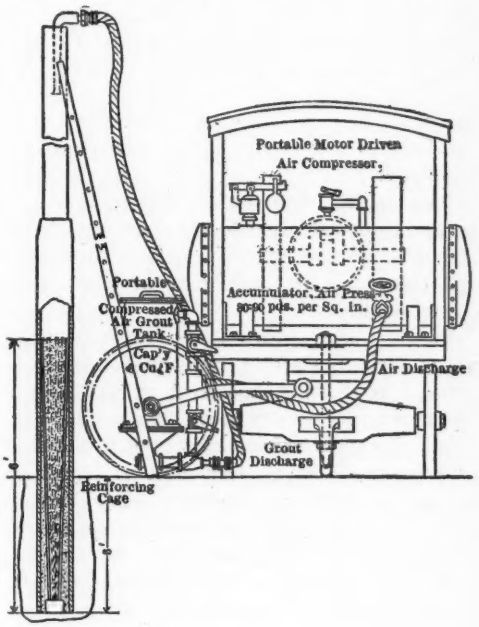
Fig. 5 shows the variation in atmospheric pressure with altitude, from which the other curves were figured. Of course, weather conditions affect the atmospheric pressure quite materially, but the curve is meant to represent average fair-weather conditions.

Fig. 6, while not of direct commercial use, will prove of interest in showing what occurs under various conditions of intake-pressure variation, and if it sheds any additional light on the somewhat complicated subject of air compression, its calculation will not have been made in vain.—*Power and The Engineer.*

REINFORCING CORRODED TROLLEY POLES

One of the largest electric railway companies in this country recently determined to strengthen several thousand trolley poles which threatened to become useless from corrosion. The accompanying cut, from the *Electric Railway Journal,* shows the apparatus employed and a description of the mode of working follows.

The workingmen who reinforce the poles are furnished either with a wagon or a ladder and a vehicle which carries a grouting tank and a motor-driven compressed air outfit operated by current tapped from the trolley wire. In repairing a pole the first step is to remove the cap from the pole and then drop into the latter a reinforcing cage built of high carbon steel twisted bars. At the factory the lower ends of these rods are set in a concrete-iron base, but at the top a hooked cap temporarily confines the upper ends of the rods to allow the cage to pass through the narrower upper section of the



REINFORCING TROLLEY POLES.

pole. Upon the withdrawal of this cap from above the rods flare out against the side of the pole, but are prevented from touching it through the interposition of shims.

The next step is to force the concrete into the pole from the grout tank by way of a line of armored hose. When enough concrete to cover the rods has been injected, the pole cap is replaced, and the setting of the concrete does the rest. The size of the rods and quantity of concrete varies, of course, with the degree of reinforcement desired, but in all cases this method brings the advantage of a reinforcement which extends above and below the ordinary limit of corrosion. It has been found that the entire process can be carried out in a few minutes, so that even in the narrowest streets there is no appreciable interference with traffic.

COMPRESSED AIR HYGIENE AND THE ADVANTAGES OF STAGE-DE-COMPRESSION

The following is condensed from an elaborate address by Dr. J. S. Haldane before the Society of Arts:

THE EARS FIRST AFFECTED.

When a man is subjected to an increased air pressure his first experience is usually a sense of pressure and discomfort, which may become an acute pain, in his ears. The middle ear is an air cavity communicating by a very restricted passage, the Eustachian tube, with the back of the nose. If this tube does not admit the air freely the pressure in the middle ear is less than outside, the drum membrane is pressed inwards, the blood-vessels of the wall of the middle ear are distended, and rupture of the membrane or bleeding is apt to occur.

Persons differ greatly in the readiness with which their Eustachian tubes pass the air, a peculiar swallowing movement at the back of the mouth will usually greatly assist the operation. To avoid risk of injury the rise or fall of pressure in the air lock must be regulated to the individual susceptibility. One minute or less for atmosphere of pressure change is not too fast for some, but others, particularly new hands, require a much slower rate. It seems desirable to restrict the air inlet to avoid sudden rise of pressure, and the man in charge should see that no one suffers pain.

DISTRESS IN BREATHING.

When a diver reaches a depth of 70 to 90 feet his breathing is much oppressed and his capacity for work is greatly diminished. It has been assumed that the pressure on the body interfers with the breathing, but the carbon dioxide in the air is the real cause. Under normal conditions the breathing is always so regulated as to keep the partial pressure of the carbon dioxide in the air of the lung cells, or alveoli, almost exactly constant. If the barometric pressure varies the percentage of $C O_2$ varies inversely, so that the pressure of the $C O_2$ itself remains constant. The respiratory center is, within very wide limits, absolutely indifferent to variations in the pressure of oxygen, the want of it only being responded to when the pressure of oxygen in the air inspired falls below about two-thirds of the normal. If $C O_2$ is present in the air inspired, the effect is to make the breathing deeper, and finally also more frequent. Unless, however, the pressure of $C O_2$ in the inspired air begins to approach the normal alveolar $C O_2$ pressure, there is very little change in this pressure, compensation being produced very easily.

The work involved in pumping compels a diver to content himself with a minimum supply of air. If when he is just under the surface of the water he has enough air to prevent the $C O_2$ percentage in his helmet air from rising above 3, while he is at work, this will keep him fairly comfortable; but if he now goes down 33 ft., the air supply being the same, the percentage of $C O_2$ in the helmet air will also remain the same. As, however, the pressure is now two atmospheres, his normal alveolar $C O_2$ per centage will be 2.8 instead of 5.6.

INCREASE THE AIR SUPPLY.

Without an increased air supply it will be quite impossible for him to maintain this percentage of $C O_2$ in his alveoli, since during work the percentage in the inspired air itself is 3, and he will suffer from severe panting. The diver must have twice as much air at 33 ft. to be as comfortable as at the surface, and at whatever depth he may be, his minimum air supply must be increased in the same proportion as the increase in absolute air pressure, or the volume of air supplied, measured at the pressure he is under must never be less than the volume he requires at the surface.

By regulating the air supply in this way two experienced divers were as free from respiratory distress at 210 ft., the greatest depth hitherto recorded, as when they were just below the surface. They could also reach this depth easily within two minutes, which showed the fallacy in the time-worn tradition that a diver should always descend slowly.

Not only is a diver's efficiency and comfort promoted by the preventing of excessive carbon dioxide pressure, but a serious danger is obviated. It not infrequently happens that a diver becomes stupefied or unconscious from the effects of carbon dioxide, and the consequences may easily be fatal, as it is very dangerous to draw a man up rapidly from a great depth, and also dangerous to leave an unconscious man at the bottom.

pressure he is under, must never be less than

In caisson and tunnels, as with individual divers, it also is necessary to insure sufficient ventilation or constant replacement of air to guard against ill effects from C O_2. To make these effects practically inappreciable it would be necessary to keep the pressure of C O_2 from ever rising above 1 per cent. of an atmosphere. When there is no other source of C O_2 besides the persons present, a minimum ventilation of 300 cu. ft. per man per hour, the volume measured at the working pressure, would suffice if the air were properly distributed. If this pressure were 30 pounds, gage, this would correspond to 900 cu. ft. of free air.

The possibility has to be borne in mind, however, of other sources of C O_2, besides other air impurities. If candles are used, or if there is blasting, or if decomposition processes are occurring in the mud, there may be present not only more C O_2, but also carbon monoxide, sulphureted hydrogen or other poisonous gases. Compressed air costs money, and it is therefore important to avoid all unnecessary sources of air impurity, so as to render excessive ventilation unnecessary. For obvious reasons the air ought also to be properly cooled before it is delivered.

CAISSON DISEASE.

Deep water divers are liable to sudden attacks of illness after reaching the surface. Sometimes death occurs, but paralysis, particularly of the legs or bladder, is more common. This paralysis often passes off after a time, more or less completely, but it may be permanent or may lead to a lingering fatal illness.

Among workers in caissons and subaqueous tunnels at high pressures similar cases of death or paralysis, or attacks of syncope, sometimes occur. Shortly after coming out of the air-lock. The most common symptom is, however, an attack of pain in a limb or sometimes elsewhere in the body, these pains being known among the men as "bends" or "scrims." They fortunately pass off soon and usually occur within an hour of leaving the air lock. The following is now accepted as an explanation:

When a gas is brought into contact with a liquid the latter takes up the gas in simple solution apart from any chemical combination, until a state of saturation is reached. The amount thus taken up depends upon the "coefficient of solubility" of the gas in the liquid and the temperature of the liquid, and varies directly with the pressure of the gas, in accordance with what is known as Dalton's Law. The blood passing through the lungs is practically in contact with the air breathed, and therefore takes up, when a man or animal is in compressed air, an increased proportion of nitrogen and oxygen in simple solution.

The increased proportion of oxygen so taken up only adds slightly to the total oxygen in arterial blood, since far more is normally taken up in loose chemical combination with the haemoglobin; and in any case nearly all the free (i. e., uncombined) oxygen of the blood disappears when the latter reaches the tissues. Carbonic acid is of course also present in the lung air to the extent of about 5.6 per cent. at ordinary pressure; but the compressed air makes no difference as regards the solution of C O_2 in the blood, since, unless the air breathed is very foul, the pressure of the C O_2 in the lung air is kept constant by the breathing, whatever the total atmospheric pressure may be.

The increased proportion of nitrogen taken up by the blood in compressed air passes to the various semi-liquid tissues, which gradually also become saturated, since nitrogen, unlike oxygen, does not disappear by entering into chemical combination. The whole body thus gradually becomes saturated with nitrogen at the pressure (79 per cent. of the total atmospheric pressure) which this gas exerts in the compressed air.

If the excess of air-pressure is now rapidly removed, as occurs when a worker in a caisson passes rapidly through the air-lock, it is clear that the blood and tissues will for a time be in a condition of super-saturation for the diminished pressure. In consequence of this the nitrogen will tend to liberate itself within the body in the form of bubbles, Just as C O_2 is liberated in bubbles when the cork of a bottle of soda water is removed. When a liquid is saturated by the contact with a gas the pressure exerted by the gas in solution is the same as that of the gas in contact with it. The gas in solution will tend to liberate itself in the form of bubbles if its pressure in the liquid exceeds the total external pressure. Thus, if the blood and tissues be saturated with air at 4 atmospheres pressure the nitrogen in solution will tend to liberate itself in

bubbles as soon as the external pressure falls below 79 per cent. of 4 atmospheres, i. e., below 3.16 atmospheres. It does not follow, however, that any actual, or, at any rate, any rapid, formation of bubbles will occur, particularly in the case of an albuminous liquid like blood; and the lowest pressure by rapid decompression from which a fatal accident has occurred in a caisson worker is, so far as Dr. Haldane has been able to ascertain, 23 lb., gage, or 2.6 atmospheres of absolute pressure, corresponding to 53 ft. of sea-water. The occurrence of symptoms of any kind is very seldom observed with pressures of less than 2.3 atmospheres, or 19 lb. gage.

Paul Bert proved by numerous experiments on animals that sudden decompression from considerable pressures commonly causes death with symptoms of asphyxia, or else paralysis. The higher the pressure, and the longer, within certain limits, the exposure to it, the more absolute the certainty of death becomes. On post-mortem examination of the bodies of the animals he found the veins in various parts of the body full of bubbles consisting almost entirely of nitrogen; and in the cases with symptoms of asphyxia the right side of the heart was full of froth, which had completely blocked the circulation.

The symptoms of paralysis were evidently due to partial or complete blocking of vessels supplying the spinal cord or brain; and in animals which had survived the paralytic attack for a few days, softening and the usual degenerative changes were found in the spinal cord at the places where the block had occurred.

Paul Bert pointed out, and partly proved by experiments on animals, that in order to avoid compressed-air illness, slow decompression is necessary. He did not, however, show how slow the decompression required to be in order to secure safety, nor has human experience solved this problem. When the excess of pressure has exceeded about 1½ atmospheres, or 22 lb., the rates of decompression hitherto employed have proved more or less unsafe if the exposure has been long continued, and the higher the pressure the greater the danger with a given period of exposure. Heller, Mager and von Schrötter have laid down a rule that for each atmosphere of excess pressure an allowance should be made of 20 minutes for each atmosphere of decompression, and that the decompression should be at a uniform rate. The rule is doubtless a great advance in some respects on what has been the practice hitherto, but the calculation on which it is based is unsound. There is no real evidence that it would afford safety for pressure of even 30 lb., while for pressures below 20 lb. a much faster rate of decompression is well known to be practically safe.

From the existing evidence as to the mode of action of the lungs it seems certain that, whatever the pressure of nitrogen in the air breathed may be, the arterialized blood leaving the lungs will be practically saturated to the same pressure. On exposure to compressed air the unsaturated venous blood will become saturated in passing through the lungs, and on return to a lower air pressure the supersaturated venous blood will become de-saturated. On exposure to a high air pressure saturated arterial blood will be flowing from the lungs toward all parts of the body. But these parts are just as capable of taking up an excess of dissolved nitrogen as the blood is. Hence during its passage through the body-tissues the blood will lose most of its nitrogen to the tissues, and the venous blood returning to the lungs will contain very little of the excess of nitrogen with which it started. In the lungs, however, it will be charged up again, though the amount which it gains there will, of course, not be quite so great as at the previous round of the circulation. At the next round the amount carried away will be still less, and so on. The process of desaturation on return to a lower pressure must take place in a similar way, provided there has been no formation of bubbles, or anything else to complicate the conditions.

The time actually required to produce any given degree of saturation or de-saturation in any part of the body remains, however, quite uncertain so far. Some parts of the body have a very rapid circulation, and will therefore saturate and de-saturate quickly. Other parts, however, have a small circulation of blood in proportion to their mass, and must therefore saturate and de-saturate slowly. We at first over-estimated the rate at which saturation and de-saturation occur, partly due to ignorance of the fact that fat dissolves about six times as much nitrogen as blood. The fat scattered throughout the body thus acts as a

reservoir for nitrogen; and this probably about doubles the time needed for saturation to occur.

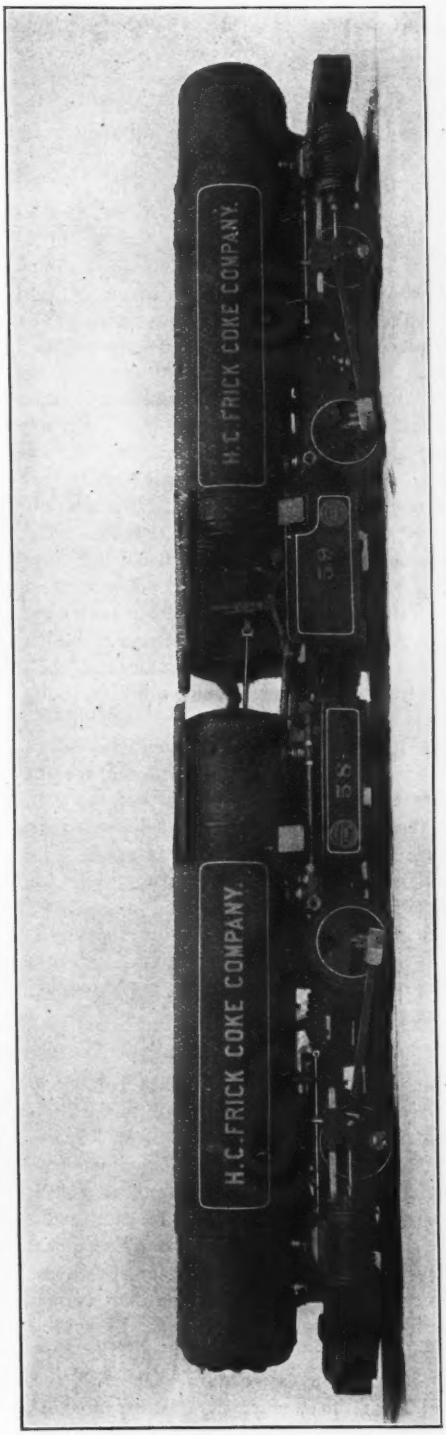
In goats some parts of the body giving rise to symptoms on decompression are not more than half-saturated in 45 minutes, and will de-saturate with corresponding slowness. The rate of circulation in man is only about two-thirds as fast as in goats. Hence, in man, there will be some parts of the body which only half saturate in 1¼ hours. Previous investigators have inferred that saturation and de-saturation occur far more rapidly than this; but the above conclusions are in accord with practical experience in caisson work. Mr. E. W. Moir, M. Inst. C. E. (of Messrs. J. Pearson & Son, Ltd.), who has given great attention to the whole subject and introduced important measures for the safety of workers in compressed air, states that even after three hours' exposure to compressed air the cases of illness are less frequent than with longer exposure; and similar evidence has been brought forward by Mr. G. W. M. Boycott. This can be well understood if the rate of saturation is so slow.

(*Continued on Page* 5123.)

TANDEM COMPRESSED AIR LOCOMOTIVES

The Baldwin Locomotive Works have recently built eight compressed air locomotives for the H. C. Frick Coke Company, a pair of them being shown in the half tone. These engines are alike except that six of them have a track gage of 3 ft 6 inches and the other pair 3 feet 4 inches. They are for a gaseous mine where the employment of electricity would be dangerous, the operating conditions requiring the hauling of heavy loads up grades as steep of 5 per cent. and around curves of 180 feet radius. The restricted clearance limits made it practically impossible to design a single locomotive meeting the conditions, so they were arranged to be operated in tandem as here shown.

The locomotives are coupled back to back, one operator controlling the two units by a single throttle lever, reverse lever, brake valve, etc., the locomotives also being charged simultamously by means of a flevible connection between the air tanks. This flexible connection is closed when the locomo-



TANDEM COMPRESSED AIR LOCOMOTIVES FOR COAL MINES.

tives are in operation, but the auxiliary, working pressure tanks are then in communication through a rubber hose, so that the cylinder pressures on the two units are equalized. This pressure is maintained by the reducing valves at 150 lbs., the initial pressure in the storage tanks being 800 lbs.

Each locomotive is provided with two air tanks, one of which is about 30 inches shorter than the other to allow room for the operator. They are built of steel plates ⅞ inch thick, being 31 ¾ inches in diameter, and the longest 14 feet 9¼ inches long. The circumferential seams are triple riveted and welded, and are further reenforced by an inside liner secured to the shell by eight rows of rivets.

The details of construction, as far as frames, running gear and valve gear are concerned, present many features similar to those of the steam locomotive practice. The frames are of cast steel, of the usual bar form in the middle and narrowed down to a slab section at each end. The air tanks are supported on cast steel saddles, one of which is bolted between the slab frames at each end of the locomotive. The cylinders, 8 by 12 inch, are cast separately and are placed outside the frames. The driving wheels are 4 feet 6 inches diameter, the combined weight of the two locomotives is 46,400 pounds, and as the normal traction force is 8,160 pounds, a liberal factor of adhesion is assured. The equipment throughout is most complete for a locomotive of this type, and special attention has been given to making the coupling devices simple and positive in action so that the locomotives can be readily operated in tandem.

SCIENCE AND SUGAR

Gallileo discovered the hydrostatic balance in 1586, but apparently did not utilize the idea, although he invented the thermometer. It remained for the pupil, Torricelli, to invent the barometer which measures the vertical weight of the atmospheric air surrounding the earth and as this could be done with the heaviest liquid we know of, mercury, or with water, the tubes, now known as barometrical, were then known as Torricellian tubes. When Howard invented the vacuum pan in 1819 he utilized the 17th century idea as to a vacuum that with the removal from the surface of a liquid mass of the weight of the atmosphere in whole or in part, the boiling point of the liquid became reduced. To operate the vacuum pan the air pump was utilized for the double purpose of removing the air pressure and also for condensing the vapor of evaporation. This method of condensation was successfully used by Howard and his successors, until about 1850, when the so-called dry vacuum, in contradistinction to the older method, then called wet vacuum, came into use. The dry vacuum method necessitated a condenser sufficiently high to balance the atmosphere, utilizing Gallileo's hydrostatic balance and an outlet sufficiently large to discharge the water of condensation into a foot tub, thus utilizing Torricelli's barometrical tube in which the height of the water counterbalanced the degree of vacuum obtained in the boiling pans. In 1870 ,there was only one vacuum pan in Louisiana that had an elevated condenser and Torricellian or barometrical tubing outlet, or that was built, as is commonly said, on the dry vacuum plan. That pan was in the sugar refinery of Paul Cook, one of our early sugar refiners, whose descendants are among our prominent sugar people of the present day. The next dry vacuum apparatus was erected at that time on Belair plantation, below the city of New Orleans, by Mr. John Dymond. Gradually the dry vacuum method of boiling came into general use and of course such use was improved with the development of sugar refining and with the more advanced methods of sugar manufacture.—*Louisiana Planter.*

AN OLD SPANISH AIR COMPRESSOR OR BLOWER

By C. F. Spalding.

I stumbled onto the remains of an old smelter a few miles from the trail leading into Tegucigalpa and about four to five days' ride from San Pedro Sula. The place was overgrown with jungle and the natives themselves knew nothing about the plant or when it was abandoned. I found it by following an old ditch line about three-quarters of a mile long, while looking for placer workings.

The dump showed about 100 tons of slag (copper) and some raw copper ore around the foundation of the stack; but what interested me most was the means they evidently used to make the air blast. Back of the stack a hundred odd feet was a small tunnel just large

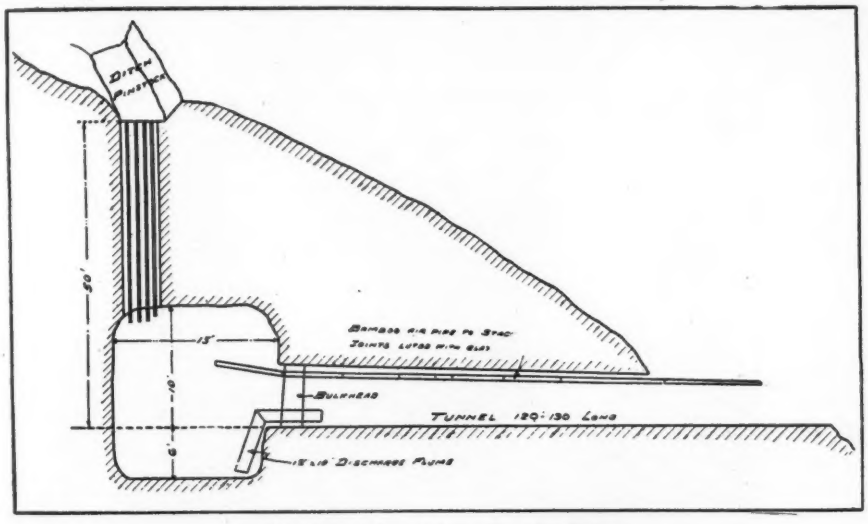
enough to crawl into comfortably. I went into it expecting to see the place from which they obtained their ore, and instead found the compressor plant.

The tunnel was driven into the side hill about 120 to 130 ft. At the inner end it was enlarged to a room about 10 to 15 ft. high 15 ft. long and 6 to 8 ft. wide. The room floor was several feet below the level of the tunnel floor, approximately 6 to 7 ft., but being partially filled with debris, sticks, leaves, etc. (packed in by tigers for their lair), it was hard to find the real bottom.

At the inner end of the room was a vertical upraise about 3ft. in diameter through to the surface. This hole was filled with bamboo pipes 6 to 10 ins. in diameter (14 pipes in all) set in clay, filling the upraise solid. This got me interested and I started to investigate. At the top of the upraise and end of the ditch was a crude penstock built with brick, showing where the water was discharged from the ditch onto the top of the bamboo pipes and flowed down the pipes. Leading into the tunnel, along the roof, was a bamboo pipe 4 to 5 ins. in diameter. This was badly rotted and fell apart on touching.

The pipes in the upraise were in a fair state of preservation. The inner end of the tunnel showed traces of being at one time bulkheaded. Running through the bulkhead was a wooden flume made from a native wood that is practically indestructible.

This flume was about 12 to 18 ins. inside dimensions and extended through the bulkhead, making a turn to the bottom of the room. Evidently this apparatus was used somewhat as follows; the water rushing down the tubes from the pen-stock would suck in air; this would be liberated in the inner room and taken out for blast purposes through the upper bamboo pipe in the tunnel, the water being discharged through the wooden flume at the bottom of the bulkhead.



OLD SPANISH HYDRAULIC AIR COMPRESSOR.

The bottom of the flume being 5 to 6 ft. below the outlet would give an air pressure of 2½ to 3 lbs. I could not figure out any other use for the layout than that of compressing air, and must say that it was sometime before it dawned on me what I was seeing. I could hardly believe that those old fellows knew enough to figure out a scheme like that.

The place had been abandoned 150 years or more, as there were trees of that age growing on the dump ditch line.—*Mining World.*

The atmospheric pressure for altitudes not excessive may be approximated by subtracting 1 inch from the barometer reading at sea level for each thousand feet of elevation. Thus at 6,000 feet this rule gives 24 inches, which is only between 0.1 and 0.2 inch too high, or much closer than any engineer reads his gage in practice.

KILLING WEEDS BY SPRAYING CHEMICALS

A company has been formed and has commenced operations whose purpose is the destroying of weeds along railroad tracks and elsewhere. The apparatus employed sprays the weeds with a chemical preparation, the theory being that the solution is breathed in by the plants, becomes mixed with the sap, and in this way kills the roots. The vegetation above ground is killed in 12 or 14 hours and it is said the roots will not sprout again. The attitude of the company seems to indicate confidence. It does not sell the apparatus nor the chemical solution, but is prepared to make contracts with railroads to sprinkle the roadbed for so much a mile under guarantee that if the weeds are not killed no charge will be made.

For steam roads the outfit consists of a 40 ft. flat car of 100,000 lbs. capacity with a 4,000 gallon tank on each end, and in the middle of the car there is a cab for the storage of the necessary chemicals and to cover steam heating and other apparatus. To effect a chemical mixture of the ingredients the water must be heated to the boiling point, which when convenient may be done by taking steam from the locomotive. The car is equipped with air compressors for applying pressure to the solution tanks so that the spraying apparatus will operate at constant pressure, regardless of the head of the water in the tank. The spraying apparatus consists of six nozzles arranged in a line crosswise under the car and near one end, with pipe connections to both tanks. The flow is automatically regulated according to the speed of the car, delivering about 500 gals. per mile, and effective work is done up to a speed of 10 miles per hour.

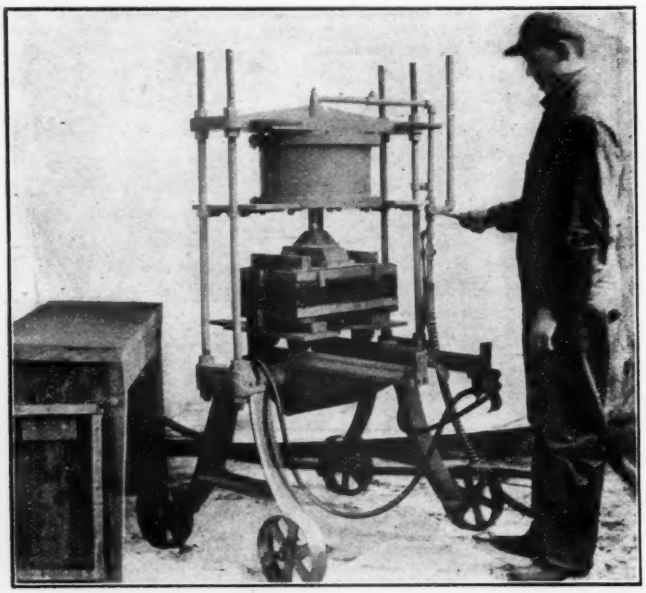


FIG. 1—RAMMING DRAG WHEN MATCH BOARD OR SAND MATCH IS USED.

"THE TWENTIETH CENTURY" MOLDING MACHINE

The half-tones show a portable pneumatic molding machine built by the J. F. Webb Manufacturing Company, Davenport, Iowa. The machine is specially adopted for general jobbing and for railroad repair work, using ordinary patterns without special preparation. It is a positive pressure machine, using air of the ordinary shop pressure. There is a light, stiff cast iron frame with legs of suitable height which have bosses for wheels which may be used or not as desired. From the frame or bed rise four rods which carry the air cylinder and pressure mechanism. Air is

admitted to the cylinder by a special valve which gradually applies the pressure to the mold, the travel being adjustable to secure absolutely uniform ramming. As was said, ordinary patterns, such as are used in hand molding, can be employed on this machine. A stripping plate can also be used to advantage. The air cylinder is 13 inches diameter, giving, with 100 pounds air, a total pressure of nearly 7 tons.

Fig. 1 shows the ramming of the drag when a sand match is used. There is a small traveler which is a part of the machine and is moved easily in or out on roller bearings. The sand can be regulated by raising or lowering the air cylinder by the nuts on the side rods.

Fig. 2 shows the machine ramming both cope and drag at one operation. This can be done when the patterns are mounted on a plate or board. The machine is made in two sizes, 30 and 36 inch.

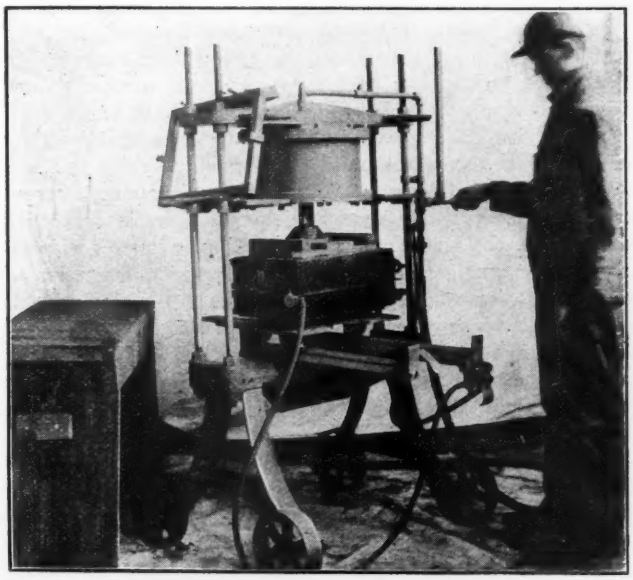


FIG. II—RAMMING BOTH COPE AND DRAG IN ONE OPERATION, THE PATTERNS BEING MOUNTED ON A PLATE.

drag part of the flask is put on and a sand frame 1 inch deep is placed on the drag to hold the extra sand required to fill the mold. The flask is filled with sand, the pressure head is placed on top and the traveler with the mold is pushed under the pressure cylinder, the air is turned on and the mold is rammed by the descent of the piston. The mold is then run out from under the cylinder, the pressure head is removed and the extra sand struck off; the bottom board is then put on and the flask rolled over, when the cope is rammed in the same way as the drag. The hardness of the

WHY A COMPRESSOR CYLINDER MUST BE WATER JACKETED

By Lucius I. Wightman.

When a volume of air or gas is compressed from a lower to a higher pressure, all the work done upon that volume is converted into heat. This is the result of an increased activity imparted by the compression to the molecules composing the air or gas, but the process by which this activity, appearing as sensible heat, is produced need not enter into this discussion.

In the modern compressor, water jackets are provided surrounding the compressor cylinder for the purpose of carrying away, so far as may be, this heat of compression. In other words, power is expended in producing heat, which is then carried away by the cooling water without any useful effect. The compression process produces heat and pressure; the jackets carry away the heat, leaving only

the pressure to show for the energy expended. Why not retain both the heat and the pressure, thus securing more nearly the full equivalent of the power used? The object of this paper is to explain this apparent anomaly.

The compression of air or gas must raise its temperature, whether the process be slow or fast. But raising the temperature of air produces one of two results. If the air volume is confined in a limited space, an increased temperature results in an increased pressure, due to the expansion of the air. If the volume is not confined, the increased temperature produces an increased volume, again due to expansion.

Assume that we have a compressing cylinder with a cross-section of 1 square foot and a piston travel of 6 feet, thus giving a cylinder volume of 6 cubic feet. Let this cylinder be filled with air at sea-level, atmospheric pressure 14.7 pounds and at 60 degrees Fahrenheit. If the piston is now advanced for one-half its stroke, or 3 feet, this volume will be compressed to one-half its former volume, or we will have two volumes in the space of one, giving, at first glance, a pressure twice as great, or 29.4 pounds. If we continue to advance the piston until it has traveled 5 feet, we will have crowded our original volume of 6 cubic feet into a space of 1 cubic foot, and we should have a pressure of six atmospheres, or 73.5 pounds, gage.

As a matter of fact, in the latter case we will have a higher pressure than 73.5 pounds, the excess being due to the heat produced in the air in compressing it from one atmosphere to six. Just what this final pressure would be cannot be stated exactly. If our cylinder and piston were so made that not a particle of the heat could escape from the air volume, its temperature at a pressure of six atmospheres would be a little over 419 degrees Fahrenheit. But as some of the heat is bound to escape, this temperature is never fully attained. However, enough heat remains to increase the pressure, at the end of six compressions, to more than six atmospheres.

It would thus seem that we had expended more power than necessary, if six atmospheres was the pressure we set out to attain. The combined effect of the heating and compression produced a pressure of six atmospheres before the piston had traveled five-sixths of its stroke, and if the discharge valves were arranged to open at just that point, we could have saved the power required to produce this excess pressure.

The difficulty is that the pressure, which is the combined result of compression and heating, is not a stable pressure. The heated air, discharged at six atmospheres, rapidly cools or loses its heat by conduction and radiation. Now, the cooling of a volume of air in a limited space reduces its pressure, just as heating it increases its pressure. The heated air at six atmospheres rapidly cools and its pressure drops, so that while we have compressed to six atmospheres in the cylinder, we actually have a pressure less than this in the pipe line available for work.

To produce a stable effective pressure of six atmospheres in the pipe lines, we must carry the cylinder pressure higher than six atmospheres, so that after the compressed air has cooled to the temperature of its surroundings, it will have the final pressure we set out to attain at our working tool. The difference between the six atmospheres on the line and the higher pressure in the cylinder represents an expenditure of power without useful effect, due to the heat of compression which was allowed to remain in the air during compression.

RESULT WHEN AIR IS COOLED.

Now what would have been the result if we had arranged to cool the air during compression? Suppose we had made the walls and heads of the cylinder double, circulating cold water in this space, moving the piston forward very slowly and giving the water time to absorb and carry away all the heat of compression as fast as it is produced. There would be no excess pressure due to heating; the reduction of the volume from 6 cubic feet to 1 would produce exactly six atmospheres of pressure, and the air at this pressure would be in a stable condition. Thus the use of the water in this case would actually have saved us the power otherwise required to produce the higher ineffective and useless pressure.

But, as a matter of fact, the condition just outlined is impossible of attainment in actual practice. Every-day results are a compromise between the two systems of compression which have been discussed.

A compressor cannot, in practice, be run so slowly as to permit all the heat to be absorbed and carried away by the jacket water. Temperature increases with the pressure, while

the advancing piston steadily reduces the cooling surface of the cylinder walls with which the air is in contact. Near the end of the stroke, when pressure and temperatures are highest, the greater part of the cooling surface exposed is the cylinder-head, thus explaining the importance of head jacketing. Heat is conducted from one particle of air to another very slowly, so that after all, the interior of the air volume is not cooled by the jacket, but only that external film in contact with the cool cylinder walls.

All things considered, therefore, water jacketing a compressor cylinder results in only a part of the saving of power which in theory it promises. Some beneficial effect along this line it certainly has, particularly in long stroke, slow-speed machines. But the full benefit of cooling during the compression can be secured only by other means—by the breaking up of the compression process into several intervals, between which the air is cooled by external means.

Cylinder jacketing is nevertheless essential in the modern air or gas compressor. Aside from the economical consideration just explained, it has other important effects on the proper operation, and indeed on the economy of the compressor.

THE EFFECT UPON LUBRICATION

Not the least important of these is its effect upon the lubrication. The compression of air from sea-level pressure and a temperature of 60 degrees Fahrenheit to six atmospheres, or 73.5 pounds, produces, unless some cooling is provided, a temperature of about 419 degrees Fahrenheit, as already stated. Such a temperature as this is destructive of all ordinary lubricants and packings, and the result would be a rapid wear of the piston, cylinder and valves, with inevitable leakage, loss of capacity, increased friction and excess power consumption. The water jacket keeps these parts reasonably cool, resulting in free lubrication, little wear, easy running and sustained efficiency.

An attempt to run continuously without jackets would heat the cylinder, valves, rods and other parts to such a degree that dangerous expansion stresses might be produced, resulting in distortion, added friction and possible breakage. The alternate expansion and contraction between the extreme temperatures of operation and shut-down would make it practically impossible to keep tight joints.

It is just as essential that air should be admitted cool to the cylinder, as that it shall be kept cool during compression. For cool air is dense air, and the cooler the air admitted, the greater in proportion the volume of compressed air delivered. The heating of cylinder walls, piston, rod, valves and ports means that the air entering the cylinder will be heated by them—first, while entering through the valves and ports, and second, by contact with the interior of the cylinder. This means lowered efficiency of the compressor and reduced capacity; and, since jacketing at best is only partially successful, this fact suggests the advantage of those constructions admitting air in a large body through one or a few large openings, rather than through a large number of small valves.—*Power and the Engineer.*

FOR SYSTEMATIC INSPECTION OF THE AIR COMPRESSORS

In the Report of the Committee on Maintenance and Inspection of Electrical Equipments, to the American Street & Interurban Railway Engineering Association, Atlantic City, N. J., Oct. 12-16, 1908, the following related to air compressors:

Your committee thought that, owing to the increased use of compressed air on city and interurban cars, it would be well for it to consider the matter of maintenance of air compressors. In order to get the ideas of the different members of the association on this subject, several questions were asked. To the question, "How often do you overhaul air compressors?" the answers shown in Table I were received:

TABLE I. OVERHAULING OF AIR COMPRESSORS

No. Roads	Compressors	Overhauling Period
1	7	150,000 miles
1	480	60,000 "
1	18	25,000 "
1	40	5,000 "
1	600	18 months
16	970	20 "
11	398	6 "
3	145	3 "
6	289	when needed
18	125	non-committal.

The duties of an air compressor on city and interurban cars vary greatly. For instance, a car may be equipped with air doors, electro-pneumatic control and air brakes. The average distance between stops

for a car of this character in city service may be every 1,500 ft. A compressor under these conditions would necessarily have to be overhauled much more often than one that made stops two or three miles apart, had no air doors or electro-pneumatic control. It also is evident that the first class of service would require a compressor of larger capacity than service of the second class. As a general proposition no air compressor should be required to operate more than 33 1-3 per cent. of the time.

The committee believes that with a compressor designed to have sufficent capacity for the service it is to perform, an overhauling for service of the first class should be made every 60,000 miles. A compressor for the second class should be overhauled every 120,000 miles. The overhauling of a compressor should be thorough, and should consist of the following:

Compressor should be taken from under the car and placed on a bench where armature should be removed, oil drained from crank case and all bearings outside of crank case, and then the bearings should be thoroughly washed with gasoline.

If wear is excessive, the crank shaft and connecting rods should have the slack taken up or the bearings should be re-babbitted or re-lined with bronz bearings, as the case may be.

The head should be taken from the compressor, ports scraped out, hair removed from hair strainer and washed in gasoline; and valve and valve seats should be reground.

Armature should be taken to the armature room, blown out, cleaned and break-down test applied. Also the commutator should be trued up. Mica retaining rings should be painted with insulating paint. Armature painted with a coat of oil-proof insulating-paint.

Brushholders should be cleaned in gasoline and overhauled, replacing worn tips and shunts that have broken strands.

Field coils should be taken out and insulation carefully looked over, and replaced if necessary.

The inside of the motor shell should be carefully cleaned with gasoline to get oil and dirt out of shell.

The committee recommends the impregnation of pump field coils as tending to cut out all field troubles and greatly prolong the life of the fields.

The piston should be removed from the pump, and the rings should be removed from the groove and carefully cleaned; also, the groove should be carefully scraped out.

Springs from piston rings should be tested to make sure that they have not lost their tension.

If, when the pump is re-assembled and started to work under pressure for five minutes, it be then disconnected and allowed to run free, and oil is discharged from the outlet, it is an indication that the rings are not tight enough in the cylinder, and springs of greater tension should be put in the rings.

The insulators placed between compressors and air piping on car should be taken from the car and cleaned and given a break-down test of 1,000 volts.

The oil which was removed from the compressor when it came in should be run through a filter and returned to the compressor, enough oil being added to take the place of dirt, etc., which it contained when removed. In this connection care should be taken to use an oil which does not contain asphalt or which will not carbonize when the pump is given hard usage.

INSPECTION OF AIR COMPRESSORS.

The frequency of inspection of air compressors should be determined entirely by the serivce to which they are subjected. In answer to the question, "How often do you inspect air compressors?" the following replies were received:

13 per cent. inspect daily.
6 per cent. inspect twice a week.
47 per cent. inspect weekly.
1¾ per cent. inspect every two weeks.
½ per cent. inspect monthly.
25 per cent. inspect from 400 to 600 miles.
1 per cent. inspect 1,200 miles.
5¾ per cent. inspect when cars are inspected.

Your committee recommends that air compressors subjected to the severe service described above under Air Compressor Maintenance should be inspected as follows (the inspection period to be based on 600 miles):

Oil plug should be removed and oil added each inspection day to replace that lost in

service.

Remove carbon brushes and inspect each inspection day.

Inspect brush-holder tension each inspection day.

Wipe off brush-holder each inspection day.

End of commutator should be wipedoff each inspection day.

Hair should be taken out of hair strainer, and strainer washed in gasoline every thirtieth inspection day.

Valves should be taken out and cleaned in gasoline each thirtieth inspection day.

Exterior of pump should be wiped each inspection day.

Compressors should be thoroughly blown out with compressed air each tenth inspection day.

Cars of the second class of service should be inspected as above, only the period of inspection should be 1,200 miles.

The committee recommends that the following tests of compressor be made after the above inspection is completed: With all air reservoirs empty and brake valve on release position, start air compressor and note length of time taken in pumping up, and pressure at cutting out point. The inspector will learn to tell when a compressor is not working properly by this method. A test for leakage should then be made, leaving apparatus in same condition as above, and noting number of pounds drop in one minute; the inspector will soon become educated to detect leaks in this manner.

NOTES ON MACHINE ROCK DRILLING

By George C. McFarlane.

For all ordinary mining work, particularly sinking and drifting in hard rock, a 3, or 3¼-in. machine, of any standard make, will give good satisfaction. Among the factors which make for fast drilling and rapid driving are good strong machines, kept in first-class repair; good air, that is, air free from entrained moisture and under a pressure of 80 lbs. or 100 lbs., or even more; sharp, square-bitted steel of the smallest possible gauge; using as few flat, dry holes as possible; and arranging the work so that the holes have good square starts. In all hard-rock mines, unless ventilation is extremely poor, it pays to drill small-gauged holes, heavily burdened, and spring them a couple of times, so that they will take big charges of explosive.

Wherever a number of machines are used, it pays to keep a good man to look after the machine repairing and attend to extending the pipe lines, and to see they don't leak. The machines should be taken apart, cleaned, and broken or worn parts replaced at least every two weeks; the brass rotating nut in the piston, particularly, should be renewed at the slightest sign of wear, as in hard, slippy ground it is important that the drill is twisted sufficiently. It also pays to frequently renew the chuck bushing, as with a worn chuck bushing it is impossible to chuck a drill straight, and the starter wobbles all over the face in starting a hole.

HIGHER AIR PRESSURES.

The increasing tendency to use higher air pressures for rock drilling is a very good one, and I have found it advantageous to use pressures even up to 140 lbs. At this latter pressure it is found that machines use very little more free air than at 100 lbs.

In places where only 70 or 80 pounds of air is carried at the compressor, the pressure at the machines is very weak, especially when two or three machines on one small pipe line are started up together. In this case the machine drags the steel back and forth and wears the gauge of the steel just as much as hard, solid blows.

One of the most exasperating features of drilling hard rock is the frequent "fituring" of the holes, caused by the steel glancing and deflecting when the hole encounters heads and slips at acute angles. When a hole fitures before it is half way down; it is impossible to finish it, and a new hole should be started at once; however, most runners will twist and pound the chuck for an hour or so before they give a hole up. The best way to guard against fituring is to have the steel gauged small, and instead of dropping the gauge 3-16 in. per ft., shade the gauge 1-8 in. or less. For 8-ft. holes, use a 2-in. starter and finish the hole 1 3-8 in. or 1 1-2 in., and use very long bits on the starters and seconds, the bits being made of cruciform steel only a trifle smaller than the gauge. These long bits tend to hold the hole pretty straight on the start. The long drills of the set should be of light steel and fitted with shorter bits, so that the drill can weave around a little to follow the hole if it runs a little

crooked. The bits should be square and the corners sharp. When starters with big wings and with the corners dubbed back are used to begin a hole, the hole will rifle more or less if the rotating mechanism of the machine is the least worn; then, as the hole goes down, the steel will be twisted with difficulty and easily sheared off by a slip.

Another advantage of using small starters and using very little drop to the gauge is, that the hole drills much faster; a 2-in. starter will drill 1 ft. in 5 min., where a 2 5-8-in. starter would require about 7 min.; from this it follows that large bits wear their gauge faster than small bits.

DRILLING SMALLER HOLES.

A couple of years ago, in the heavy rock cuts along the line of the C. P. R. R. and G. T. P. R. R., in New Ontario, the deep holes in the hard granite and trap would be started with 3 1-2-in. and 4-in. starters. Now, many of the contractors are putting down 25-ft. and 30-ft. holes and starting them with 2 1-2-in. bits, and the drills are turning out 40 per cent. more footage.

In the Dutton tunnel, near the Winnipeg river crossing of the Grand Trunk Pacific, the semi-circular heading, 9 ft. high and 16 ft. wide, was driven through extremely hard granite with two Electric Air drills. A round of 28 holes, each about 10 ft. deep, were drilled. These holes were started with a 2-in. drill and finished with a single-bitted 1-in. steel, the bit being just a shade larger than the steel. These small holes drilled very fast, an average footage of 45 ft. being turned out by each machine in a shift. One of the machines made 97 ft. in a 10-hour shift. After the round of holes was drilled, and the machines rigged down, all the holes were sprung twice, an average of 3 sticks being used for the first spring, and 6 sticks for the second spring, the 6 in-cut holes being sprung the heaviest.

SPRINGING THE HOLES.

It took 4 men 3 hours to spring the holes twice, after which they were allowed to cool 2 hours before tamping in the blasting charge. Thus the springing required just about half a shift. When the holes were sprung they broke clean to bottom, and the roof and sides were left in good shape, not requiring any more scaling than was necessary before using the spring method. When drilling the small holes, the two machines would put in a round of 10-ft. holes in three shifts, each round advancing the heading 9.2 ft. On the start, before the foreman tried springing the holes, it was necessary to drill very large holes in order to get enough dynamite in the bottom of the hole to break the ground, the holes being started with a 2 3-4-in. bit, and finished at a depth of 9 ft. with a 1 15-16-in. bit. It required 5 shifts for the machines to put in a round, and the average break was 7.4 ft. per round. This gives an idea of the economies that can be effected by springing holes where the rock is very hard. Of course, the method would hardly be applicable to softer rock, as it would probably be cheaper to drill a larger hole than to spend time and explosive chambering out a small hole. This, however, is a matter of direct calculation from actual demonstration.

It is always good policy, when driving drifts and crosscuts in hard ground, to drill the full round before blasting. In some localities the machine men drill and blast the incut first, and then rig up and drill the squaring. When this is done, they always get poor starts for the squaring holes, as a slanting face is left when the cut holes kick out, and it takes as long to get a hole started, in hard rock, on a slanting face as it does to drill the entire hole after the start is made. For the same reason, I prefer a "V" in-cut to a "draw" or "side-cut," unless there is an exceptionally good floor or slip to break to. With a side or bottom in-cut, most of the holes have to be started on a bad slant, while with a "V" cut all the holes go in very nearly square with the face, and, by springing the cut holes twice, or even once, it is possible to get clean breaks every round.

The machine steel should invariably be made on the ground, as it can be made by any fairly good blacksmith for a great deal less money than the manufactured bits can be purchased for. For making machine bits, the common grades of bar and cruciform steel, costing from 7 cts. to 8 cts. a pound, is just as satisfactory as the high-grade brands of American and English tool steels, costing up to 20 cts. a pound. Every mine blacksmith has some particular fad about making or tempering drills. To handle the work to the best advantage, the blacksmith should be able to make good steel welds. Of course, it is possible to make a bit by upsetting the steel, but it can be made in half the time by welding on a short length of cruciform steel. While it is essential that a

bit should be properly tempered, it is just as important that the bit be properly made and the steel worked properly every time the bit is sharpened. The wings of the bit should be equally proportioned, rather heavy, the corners should be square, and the shoulders slope back very gradually from the cutting edge. In making the bit, care must be taken not to chisel into the core of the bit in splitting, because, when the core is deeply chisel-marked, the corners will break off in tempering. In sharpening a dull bit, most of the work should be done with a cross-peined hand-hammer; with light, quick blows of the pein of the hammer, the metal is worked from the center outward to the corners and down to the cutting edges; and many times this hand-hammering will be all the sharpening that is necessary. Every second or third dressing the bit will have to be squared up with a dolly and side-flatter and gauged with a half-round swage.

Of the many different ways of tempering machine drills, I have found the following to give the most uniform results: After the bit is sharpened, it is heated up to a bright red heat; at this heat the surface will mottle with little blisters or blebs if the drill is pulled out of the fire. At this heat, or even hotter (as the exact degree of heat does not seem to be important), the drill is shoved about an inch into the water, swished around to keep the point sizzling in fresh water, and occasionally soused to gradually cool the bit back of the cutting edge. In about 20 seconds the bit can be dropped into the tub. This method of tempering makes only the cutting edge hard, and also seems to toughen the bit. Another method which gives good results but takes more time, is to let the bit get cold from the sharpening heat, then heat to a cherry red and plunge into the tub, take out, warm it over the forge, swab it with black oil, burn the oil off and again plunge in the tub. Ordinarily, blacksmiths throw the drills into the tub, right off the anvil. Generally they are not hot enough to take a hard temper, and they are heated so far back that when they do break off, about half the bit stays in the hole.

DAMP AIR.

In low altitudes, particularly on hot, muggy days, the air coming to the machines is often wet and gives a good deal of trouble by freezing up the exhaust ports and stopping the machine. In one mine where the air was continually freezing in the machines, I found the air as it came from the compressor was so hot that you could not hold your hand on the air receiver. I particularly remedied the trouble in this instance by covering the receiver with burlap and spraying it with water from a perforated pipe, which cooled the air enough to condense a considerable amount of the water, thereby trapping it in the receiver.—*Mining Science.*

TRAPPING RATS

Engineers and contractors sometimes find rats a nuisance, or worse, in their workings and have to take measures for their extermination. The following is a summary of a collection of articles written by the employees of the U. S. Public Health and Marine Hospital service engaged in rat catching at San Francisco. These men have demonstrated their knowledge of the subject by continuous large catches, and what is here detailed is the result of actual experience; it will be found to be highly interesting reading and the information conveyed is out of the usual run.

Rats are to be found where there is an abundant food supply, and the best places to trap them are slaughter houses, meat markets, chicken houses, and wherever garbage is accumulated. If a rat is deprived of this food supply it will be attracted by the bait and enter the trap.

When rats are plentiful the large 19 inch French wire cage trap has given very good results. It should be made of stiff, heavy wire and be well reinforced, as a large, strong rat will force his head between the wires of a weak trap and escape. The lever on the trap should be tested to see that it works properly. The trap should be placed on a hard surface with the rear end a little higher than the entrance so that the trap will close promptly. When setting the trap in an open place it should be fastened to a board on which about an inch of soft earth has been spread. Place the trap where rats usually go for food, or in a runway, and disturb the surroundings as little as possible. It is sometimes well to place the trap near dripping water, as the rats may go there to drink. If the trap is set in hay, straw or wood it should be covered (except the entrance) with the same material. When this is not possible, it should be covered with a

piece of sacking, or placed in a dark corner or beneath the floors. When setting the traps in a sewer a dry place should be chosen.

The rat is more or less of an epicure, therefore the bait should be changed at frequent intervals. For bait the rat should be given food which it is not usual for him to obtain. In a meat market, for example, vegetables are the best bait, while in a location where vegetables are plentiful, fresh liver and fish heads or a little grain are best. The following may be suggested as good bait to be used: Fish, fish heads, raw meat, cheese, smoked fish, fresh liver, cooked corned beef, fried bacon, pine nuts, apples, carrots, and corn. When trapping in chicken yards a small chick or duckling is a remarkably good bait. When a large number of rats are caught in one trap, search for the female rat and leave her alive in the trap, as she may call in the young or the males. The bait should be fastened to the inner side of the top of the trap with a piece of fine wire, so that the first rat that goes in can not force the bait underneath the pan and thus prevent the entrance of other rats. A few grains of barley should be scattered near the entrance of the trap and a small piece of cheese or meat fastened to the pan with a bit of wire. It is often well to touch the pan with a feather which has been dipped in oil of anise or oil of rhodium. The trap should be smoked with a piece of burning newspaper to take away the smell of the human hands, or of rats which have been caught in the trap. Do not handle the trap after burning it out. When trapping in a neighborhood where rats are known to exist, the traps should not be moved for three or four days unless they have rats in them, as it is well for the rats to become accustomed to seeing the traps and thus careless about entering them. It is not wise to kill rats where they are caught, as the squealing may frighten away the other rats.

Snap or spring traps are best for use in houses and stores, with the exception of fish and meat markets. Snap traps are best for use in runways and on beams and shelves. It is sometimes well to disguise the trap by covering its floor with a little sawdust or dirt. The traps should first be tested to see that they work properly and that the staples are secure. New traps should be smoked or stained to render them of an inconspicuous color.

The bait should consist of some firm material, such as fried bacon or tough meat, and should be tied on so that the rat will be obliged to pull on it and thus spring the trap. The trap should be placed in a corner or close to the wall on a flat, hard surface in order that the rat cannot spring it with his tail or by walking on it.

In warehouses and granaries large numbers of rats may frequently be trapped by using a barrel or garbage can having a metal top which is carefully balanced. A large piece of strong cheese is placed in the middle of the cover and a plank laid from the floor to the edge of the barrel. The rat runs up the plank and on the smooth lid, which tips, precipitating the rat into the barrel.

DAMPNESS AND DYNAMITE

Dynamite should never be stored in tunnels nor in any place where dampness exists. Although a tunnel may seem dry, all rock-in-place contains from 3 to 8 per cent. of moisture, which is continually being brought to the wall-surface in underground workings by capillarity, where it is evaporated unless, for want of ventilation, the air is saturated. Thus the rock is continually contributing moisture, which is greedily absorbed by the sodium nitrate in the dynamite, that salt being highly hygroscopic. As soon as the sodium nitrate has deliquesced, that is, melted from absorption of moisture, the homogeneity of the dynamite becomes disturbed, and the "dope" fails to retain the nitroglycerine, which then leaks out. The watery substance often seen on cartridge-paper, and the oily stain seen in dynamite boxes, is due to the leaking of the nitroglycerine. A cartridge in this condition is far more liable to accidental explosion than sound dynamite, and it is perilous and uneconomical in use. It will not develop the same energy as good dynamite; it is likely to burn and blow out instead of detonating properly; and it is a frequent cause of "misfires," and of the failure of a charge to explode to the bottom of a hole. —*Mining and Scientifi Press. c*

To ward off the evil of gas leakage, concrete curbing 5 ft. deep has been built around the new parks in Chicago.

COMPRESSED AIR MAGAZINE

EVERYTHING PNEUMATIC

Established 1896

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ANOTHER VOLUME COMPLETED

The present issue completes another volume—the thirteenth—of our COMPRESSED AIR MAGAZINE, and gives occasion for a word as to what has been done, and especially as to the work ahead.

It is gratifying and stimulating to note that the use of compressed air as a means of power transmission, and for the multitudinous employments for which it is especially adapted, is rapidly and continually extending, and that every new job which it gets it holds, with no diminution in any of its already established activities. Compressed air apparatus is continually being developed and improved and added to, and those interested in it and seeking information concerning it are becoming more numerous.

Compressed air has won its way not always by undertaking in advance to do its work cheaper than any other agent, measured always by the power cost alone, but rather by its instant and constant readiness for action and its precise adaptability to certain lines of work, and these characteristics, which should recommend and advance any prospective worker, have led to appreciation and constantly widening employment. The extension of the uses of compressed air during the life of this magazine has been really quite astonishing. Not to go into details at all, those sufficiently informed will surely concede at least a tenfold increase in these thirteen years, the increase extending in every direction, the number of compressors, the number of air operated apparatus, the number of distinct and specific operations, and necessarily also a similar increase in the number of firms and individuals using it and seeking, or welcoming when not sought, newer and fuller knowledge which will still further extend the field of its activities.

It is to be remembered that the indefiniteness of the term "compressed air" makes it all-comprehensive. All air of which we can have any knowledge is compressed air. "Free" air, at whatever altitude, is always compressed by all that is above it, so that in treating of compressed air and its relations with things in general we necessarily have to do, as our sub-title suggests, with "everything pneumatic." No periodical of a technical character within our knowledge has so wide a reach of interests to cater to as ours, and if we have failed,

as we have and must, to adequately serve them all, we may at least hope and resolve to have a wider and a widening influence in the future.

What success we may have must depend largely upon our readers. With a field so entirely and exclusively our own, with no other periodical in the world in competition, with so vast and diverse interests to cater to, our position is really unique in the technical press. What subscribers and readers and advertisers we have have come to us practically unsolicited, in which particular we have no doubt been remiss. Our record is deplorably unique. While advocating so constantly the use of compressed air we have employed none of it for the blowing of our own horn.

THE A. S. M. E. RELEASES ITS PAPERS FOR ADVANCE PUBLICATION

Editor Compressed Air:

We are pleased to announce that the Society has determined to release the papers to be presented at its meetings for general publication in the technical magazines, immediately after such papers appear in The Journal. The former rule has been against allowing them to be published, even in abstract, until after they were presented at a meeting. The Society is anxious to facilitate, further, the reprinting of papers published in The Journal and discussions upon them contributed at the meetings, and, upon request, will furnish, at cost, verbatim reports including the discussions of papers presented.

The American Society of Mechanical Engineers,

LESTER G. FRENCH, Editor.

NEW BOOKS

American Machinist Handbook and Dictionary of Shop Terms, by Fred H. Colvin and Frank A. Stanley, Hill Publishing Company, New York, 544 pages 4¼ by 6⅞ inches, bible paper, full gilt, limp leather cover, price $3.00. This book, prepared by two graduates of the shop, is packed full of tables, rules, formulas, data and general information, much of it new and all in readily usable condition, for machinists and workers in all the allied trades, for draftsmen and engineers, and represents in its preparation a vast amount of honest, skillful work dominated by exacting judgment. The dictionary portion is quite encyclopedic in character.

A Pocket-Book of Mechanical Engineering, by Charles M. Sames, Third Edition Revised and Enlarged, Jersey City, N. J., Charles M. Sames. 195 pages, 4¼ by 6¾ inches, ⅜ inch thick. Price $2.00. This is in fact as well as in name a pocketbook, and can be carried constantly without a suggestion of inconvenience. It is quite probable that so much in the way of tables, formulas, data, theory and examples was never before got into the same space. The book has a very satisfactory index.

How to Build up Furnace Efficiency, by Jos. W. Hays, Combustion Engineer, Jos. W. Hays, 601 Hartford Building, Chicago, 48 pages, 3½ by 6¼ inches. Price 50 cents. "There are dollars to be saved at the furnace from the book that the way to save dollars and only dimes at the engine," and we gather from this book that the way to save the dollars is to persistently use a "gas analysis instrument."

TRADE PUBLICATIONS

Catalogue Number 5, American Spiral Pipe Works, Chicago, 80 pages, 8 by 10¼ inches. This catalogue gives full information, with dimensions and price lists, of Spiral Riveted Pipe, Forged Steel Pipe Connections, Exhaust Steam and Hydraulic Supplies. Many photos and blue-print profiles and maps are given of long water supply lines, both for municipal service and power transmission. Various useful tables also are included.

Riveters, Catalogue No. 3, Hanna Engineering Works, Chicago, 64 pages and cover 6 x 9 inches. The riveters described have a movement giving the large opening of the toggle joint with increasing pressure in the advance and a simple lever action through a considerable space under approximately maximum pressure, thus producing hydraulic results with a pneumatic riveter. Many styles, sizes and applications of the riveters are shown. Hydro-Pneumatic Riveters also are described, and various other manufactures of the firm.

AIR TOOLS IN THE BOILER SHOP

Editor the Boiler Maker:

In all up-to-date boiler shops various kinds of air tools are being used: the air hammer for riveting, calking, chipping, etc.; the motor for drilling, tapping and countersinking and

the jam hammer for bucking up rivets on mud rings and air drums. Air tools are also extremely useful in flue work, as they can be used for rolling, balling over, beading, etc.; but, of course, judgment must be used when using them for such work, as there is danger of overworking the flues, whereas the hand is very sensitive, and tubes can be set by hand without any danger of injuring the tube. Care must be used not to roll the flues too much, just the same as when driving rivets, the proper length must be chosen to give a good, full head.

Large air clamps for flanging are also a handy device for forming flue sheets, etc., as the hot sheet can be quickly clamped and then pounded into shape with heavy mauls. The furnace for heating the sheet can be run by oil and air, and with such a furnace the sheet can be heated evenly all over in one heat, and thus a vast amount of time and trouble saved. Also in reaming out, tapping and running in staybolts an air motor saves a vast amount of time. In fact, there is scarcely an air tool built for use in a boiler shop which is not a time saver.

HARRY JEWELL.

COMPRESSED AIR HYGIENE

(*Continued from Page* 5109.)

Practical experience of work in compressed air shows that even with very rapid decompression no symptoms of caisson disease occur with an absolute pressure of less than two atmospheres, and that symptoms are very rare and slight until the pressure rises beyond 2.3 atmospheres, or 19 lb. gage. This was found to be true also for goats. Now, if it is possible to decompress rapidly and with safety from two atmospheres, or a little more, to one atmosphere, it seemed likely that it would be possible to decompress with equal safety from four atmospheres to two, or from six to three, since the volume of gas tending to be liberated would be the same in each case. Experiment showed that this was the case, and that the danger of rapid decompression depends, not on the absolute difference between the initial and final pressure, but on the proportion between the two pressures. If this proportion is only 2, or 2.3 to 1 the decompression is safe; if, on the other hand, the proportion is 3 or 4 to 1, the decompression is dangerous.

The method hitherto recommended for bringing men safely out of compressed air has been to decompress at a slow and uniform rate. But calculation on the principle already referred to shows that, however slow this uniform decompression may be, the difference in partial pressure between the nitrogen dissolved in the tissues and the external air-pressure will go on increasing during the decompression. Still more will the proportional difference between two pressures increase. At the end of the decompression, therefore, the danger, if any, will be at a maximum, whereas during the first half, or more, of decompression time is simply being wasted, or much worse than wasted, if saturation of the body has been incomplete. All experiments confirmed this theoretical deduction.

STAGE DECOMPRESSION.

These considerations led to a new method, that of decompression in graduated stages. The principle of this method is that the worker in compressed air is brought rapidly to half the absolute pressure (or a little further if his tissues are not saturated), stopped there for a time, then decompressed a little further after sufficient time has elapsed to allow the maximum nitrogen pressure in any part of his body to become not more than twice the nitrogen pressure of the air at the lower stage. He is then brought on by further stages on the same principle until he reaches atmospheric pressure. For the difference between the stages a pressure of 0.3 atmospheres was selected, corresponding to 10 ft. of sea-water. The proper stoppages, after stays at different depths, and for different periods of time, have been carefully calculated and put into the form of a table, which is now in use in the Biritish Navy. This diving table extends to depths up to 204 ft.

For ordinary diving work the table limits the stay on the bottom in such a way that the diver can come up safely within half an hour. This is desirable for many reasons. After prolonged stays on the bottom at great depths the time required for safe decompression, even by the stage method, is far too long; and with uniform decompression many hours would certainly be needed at the greatest depths.

The method of stage-decompression was very thoroughly tested on goats, and compared with the old method of uniform decom-

pression. The result was to show beyond all question that the stage-decompression method is greatly superior, particularly for diving work. Even when the rate of decompression was much too fast by either method, stage-decompression proved considerably safer. With goats it was necessary to provide for parts of the body taking as much as 45 minutes to become half-saturated or half-desaturated after a given alteration of pressure. For man we therefore consider it necessary to provide for parts requiring 75 minutes, as the respiratory exchange per unit of body weight in man is three-fifths that of goats.

In the case of caisson and tunnel work, the conditions are somewhat different from those in diving. In the first place, the pressures are not so high, while the period of exposure is usually longer—seldom less than three hours in the case of ordinary workmen. In the second place, there is not the same need for limiting the time spent during decompression, and therefore also limiting the period of exposure. Another important difference is that the occasional occurrence of symptoms in the air-lock is not a matter of such importance as in the case of a diver under water. The man in the air-lock has others to look after him, and he can be promptly relieved by raising the pressure. The occurrences of symptoms after he leaves the lock seems to be a matter of more moment, as it might be some time before he could be re-compressed, and he might have no one to help him.

Bearing in mind these circumstances, it seems desirable to adopt a somewhat slower rate of decompression in the case of caisson workers than in the case of divers who have been equally long exposed, and to make the decompression more gradual towards the end, so as to avoid any risky state of super-saturation in the body of a man after leaving the air-lock. The slow part of the stage-decompression then becomes theoretically very nearly uniform, so that a uniform rate may well be adopted. This considerably simplifies the carrying out of the slow part of the decompression, and the directions for the whole process.

The initial rapid stage would be to half the absolute pressure, and no slow stage at all would be needed if the pressure in the caisson did not exceed about 2.2 atmospheres in absolute measure, or 17½ lb. of excess pressure, since practical experience seems to show clearly that it is safe to decompress in three minutes from 17½-lb. pressure, or a little more. One or two exceptional cases where symptoms have occurred, though not of a serious nature, are, however, on record.

In order to avoid any chances of mechanical injury to the ears, and to keep within limits tested by practical reference, not less than two or three minutes should be allowed for the rapid decompression, and the outlet tap should be so regulated as to prevent a faster rate. If two or three minutes in all were taken the rate of fall of pressure would, however, naturally be much faster at the beginning than the end of the process, which would be an advantage. An accurate and easily read pressure gauge in the lock is, of course, essential, and it would also be desirable to have a graphic record of each decompression. The accompanying table shows the number of minutes to be allowed for each pound of decompression after the first rapid stage has been completed in 3 minutes. It has been taken into account that men will usually come out for meals after periods of about three hours work, and that, since they will not have time to desaturate during the interval, they will be more highly saturated after a second or a third period of work than after a first.

RATE OF DECOMPRESSION PER POUND.

Gage Pressure.	A	B	C
18-20.....	2	3	5
21-24.....	3	5	7
25-29.....	5	7	8
30-34.....	6	7	9
35-39.....	7	8	9
40-45.....	7	8	9

A—After first 3 hours exposure.

B—After second or third 3 hours exposure, showing an interval for a meal.

C—After 6 hours or more of continuous exposure.

To illustrate the use of the table, first suppose that the pressure in the caisson or tunnel is 23 lb. by gauge, corresponding to an absolute pressure of 38 lb. The pressure in the lock can be reduced in three minutes to 19 lb., corresponding to an excess pressure of 4 lb. by gauge. The pressure will then be allowed to fall to normal, either uniformly or by about a pound at a time, in 12 minutes, so that 14 minutes in all will be spent in the lock after the first spell of about three hours' work. Af-

ter a second or third spell, 22 minutes will be needed. With a continuous exposure all day, 30 minutes would be needed.

It will be seen that at high pressures there would be a saving of time in the lock if the men remained continuously in the compressed air. The time in the lock is, however, in any case very long at the higher pressures. This seems inevitable if a reasonable standard of safety is to be reached; and the aim of the table is to give about the same safety for work at over 20-lb. pressure as exists at present with work at under 20 lbs. Such a standard can only be reached by giving the necessary time for decompression, and the rates of decompression hitherto usually adopted are unsafe, particularly if the decompression is uniform.

With such long times spent in an air-lock, ventilation becomes necessary, and in order to permit of this it would probably be convenient to have an outlet provided with an adjustable safety-valve, so that the pressure could be kept steady at any point in spite of the influx of air. The lock should be large enough for a whole shift, and should contain an electric heater and telephone.

In order to avoid the tedious and prolonged stays in a small air-lock, it would probably be convenient in many cases to arrange for a roomy air-lock, or section of tunnel, kept at a constant pressure of 1-2.2 of the absolute pressure in the working space, with two small locks for passage to the working space, and to the outside. The men could be detained in this "purgatory" airlock for the necessary time, and then proceed rapidly through the small lock to the outside. By this plan no lock would be blocked for more than three minutes at a time, and if the men could wash, change, and take meals in the "purgatory" lock a great saving of time would be effected. If, for example, the working pressure were 30 lb., the "purgatory" lock could be kept at 5½ lb., and the men would need to stay in it about 50 minutes on their way out.

ALIVE IN CAPSIZED VESSELS

We read in Pearsons' Weekly of the remarkable escape of a sailor near Newcastle, New South Wales. The barkentine Kate Tatham turned turtle in a gale, and one of the crew was shut up in her hold. The survivors, who had climbed on her keel as she heeled over, naturally took it for granted that he was drowned. What was their surprise therefore presently to hear faint knockings from beneath their feet, evidently made by their imprisoned comrade. Help was at hand, and a hole was cut through the ship's bottom, when the man was hauled out, little the worse for his terrible experience. He had, it appeared, been kept alive by the air which had been imprisoned in the hull when the vessel capsized and which, becoming compressed as the water rose, had eventually stopped its further encroachment. He had used a balk of floating timber to support himself. We may suppose that lively work was called for when the hole was opened, as the air must have blown out rapidly and the man might have been drowned after all by the water rushing in from below.

The man's imprisonment lasted for two hours, and in the cabled reports, the incident is characterized as unparalleled. This, however, is by no means correct. There are several cases on record of men having lived in similar circumstances in the hulks of capsized ships not hours only but days, the most remarkable authenticated instance being that of Capt. Engallandt of the Erndte, who was rescued alive after an entombment lasting altogether eleven days eighteen hours. During this period the derelict, drifting bottom uppermost, was sighted by the masters of several vessels, all of whom, however, passed nonchalantly by, none imagining for a moment that the semi-submerged and capsized hulk contained, shut up in its vitals, a living man. Eventually the Erndte drifted ashore near Danzig and Capt Engallandt was taken out alive, although greatly emaciated.

THE WET-BULB HYGROMETER

Various instruments, in addition to the chemical hygrometer, have been developed for measuring the hygrometeric state of the air. The devices are purely empirical in their methods and in the results attained. Thus the wet-bulb hygrometer consists simply of two thermometers, one of which registers the temperature of the air and the other registers a different temperature which is attained by the following process: The bulb

of the thermometer is surrounded by lamp wick, which is connected to a small vessel containing water. The wick draws up moisture from the water and evaporation occurs from its surface into the air. The rapidity of evaporation depends upon the relative dryness of the air. The water in its evaporation absorbs its own heat of liquefaction from surrounding bodies and produces a distinct cooling effect on the bulb of the thermometer. similar to that of the refrigerating machine.

THE CHEAPNESS OF WATERWORKS ENGINEERING

There are now on the Croton watershed, which is depended upon exclusively for the present water supply of Manhattan and the Bronx, nine separate dams, with another under construction, which will have an aggregate storage capacity of 104 billion gallons. It is found that a large additional storage can be secured on the east branch of the Croton River, above the present Sodom or East Branch reservoir. The estimated cost of the work for dam and accessories is $3,250,000, while the additional storage provided would be 20 billion (20,000,000,000) gallons. The cost per gallon, therefore, would be about one-sixtieth of a cent ($0.0001625) and the reservoir presumably good for a hundred years.

ANTHRACITE AND BITUMINOUS COAL DISTRIBUTION.

Outside the 480 square miles of the well known anthracite region of Pennsylvania in the counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, Dauphin and Sullivan, there is hardly any true anthracite found elsewhere in the United States. In two small areas in the Rocky Mountain region coal has been locally anthracited, but the production has never amounted to as much as 100,000 tons in any year. The bituminous and lignite fields, on the contrary, are scattered widely over the United States, including an area of 496,000 square miles, divided into the six provinces, the Eastern or Atlantic Coast, the Gulf or Southern States, Interior or Mississippi Valley, the Northern or Great Plains, the Rocky Mountain, and the Pacific Coast. Bituminous coal is thus produced in twenty-six states and territories, and forms by large odds the greater part of the total production.

NOTES

The common building brick is the most widely spread of all clay products, being reported from every state and territory. In 1907, 9,705,698,000 common brick, valued at $58,785,461, were produced in the United States.

Isaac Charles Johnson, said to have been the inventor of Portland cement, is still living at Gravesend, England, at the age of 98. At his birth George III was king, Jefferson was president and Napoleon was at his greatest. Johnson became an architect and a house of his building is still standing at Swanscourt in Kent. This was the occasion of the Portland cement invention or discovery.

There has been recently patented in the United States by a citizen of Roumania, a method of preserving live fish during long periods of transport or storage. The process consists in continuously drawing off water from the tank containing the live fish, bringing this water into intimate contact with ozone, thereby "regenerating" the water, returning this regenerated water to the tank, and maintaining the water in the tank at a low temperature so as to control the movements of the fish. The original water in the tank is supposed to be water in which the fish had their natural habitat when caught. In transportation the water in the fish tanks is drawn through an ozonating device in the end of the car and returned to the tanks by means of a small pump, thus keeping up a constant circulation of the water and cooling said water at the same time by means of ice.

A pipe a yard long holds as many pounds of water as the square of its diameter in inches, very nearly. Thus, a pipe 30 ft. long and 2 in. inside dia., will hold 2x2x10=40 lbs. of water.

Apply soapsuds with a small brush to joints or fittings in an air pressure system to find leaks. It makes no difference how small the leak may be it will at once show up by the foaming soap bubbles.

Experiments which have been made abroad indicate that the heat of the exhaust of a gas engine will produce 1.1 to 1.5 pound of steam per horsepower hour, or it would be

sufficient to raise from 600 to 820 pounds of water from the freezing to the boiling point. Arrangements are being made looking to the utilization of this waste heat.

It is stated that it takes fully ten days of continuous working of the refrigerating machinery on board ship to reduce the temperature of a cargo of fresh fruit to the point at which it may be safely held, viz.: 36° to 38° F., because of the heat in the fruit itself. The internal heat of the fruit is rapidly removed in the pre-cooling systems now in use in America, and hence such precooled fruit can be shipped long distances without deterioration.

Gerald Stoney recently remarked before the British Association that there is as much power in steam from atmospheric pressure down to 27½ inches vacuum as there is from 150 pounds down to atmospheric pressure, and that the power of a non-condensing plant can be doubled by the addition of an exhaust steam turbine and condenser, and in cases where there is not a supply of cooling water improvements in cooling towers have made them cheap and efficient.

The expression 3 degrees K, means 3 degrees, centigrade, above absolute zero, the expression being derived from the name of Lord Kelvin, who first defined the zero of the absolute temperature scale. This temperature, equal to about—455 Fahr., was obtained by Professor Omer when liquifying helium. He kept helium at a temperature of 4.5 K for two hours, and finally evaporated the liquid under the pressure of about 1 centimetre of mercury, or close to absolute vacuum, when the temperature was estimated to be about 3 degrees K.

A grain elevator exploded recently at Richford, Vt., killing 15 workmen in the elevator and 2 women who were walking on the tracks near the building. The explosion is ascribed to accidental or spontaneous ignition of grain dust. The corrugated iron roof was blown off and portions of it were carried more than a quarter of a mile away from the building. Several freight cars near the elevator were broken up and overturned. The fire which followed completely destroyed the elevator and adjoining power-house, a flour warehouse and 75 freight cars.

Meteors prove that the air is still dense enough to make those little bodies incandescent through friction at a height of one hundred miles; but up to the present, man has succeeded in exploring the atmosphere to a height of only sixteen miles. The greatest authentic height attained by a human being is 35,000 feet. Kites have flown to a height of 21,100 feet, and an unmanned balloon, carrying recording instruments, has reached 85,000 feet—a little more than sixteen miles.—*Youth's Companion.*

In the Bakerloo, Hempstead and Piccadilly (London) "tubes" they have just ended a great rat exterminating job. In these underground railways the rats have been multiplying until the insulation of the electric wires and cables was all disappearing before their voracious appetites. As ammunition a thousand tubes of a special virus were judiciously distributed over night, the first effect of the virus being to create a demand for the upper air similar to that experienced by a victim of *mal de mer.* In the morning Trafalgar Square and the outsides of other stations were strewn with thousands of carcasses.

The pneumatic tube system in the service of the New York post office is being rapidly extended. Heretofore the connection with the general post office did not extend beyond station G at 51st street and Broadway. It has now been extended to 124th street west and 125th street east, with several intermediate stations. The extension just completed links Station P, in the new Custom House, the Wall street station, the general post office and all the West Side stations as far as 124th street, except four which will also soon be connected. The east and the west sides also are connected and the east side lines also will be extended to Harlem.

The total excavation on the Panama Canal for September was 3,158,886 cubic yards place measurement, against 3,252,506 cubic yards in the previous month and 1,515,212 cubic yards in September, 1907. There were 25 working days in September, against 26 working days in the previous month of Au-

gust, while the rainfall for September was 9.72 inches against 11.93 in August. The average daily output for September, 1908, was 126, 355 cubic yards, against 125,096 cubic yards in the previous month and only 56,-118 cubic yards in September, 1907. Of the September excavation 3,089, 851 cubic yards were removed from the canal prism, against 3,152,471 cubic yards in August and 1,481,-307 cubic yards in September, 1907.

Total excavation since May 1, 1904, when the United States began this work, 50,506,-317 cubic yards out of an estimated 142,-000,000 cubic yards then to be excavated.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D C.

OCTOBER 6.

900,132. AUTOMATIC AIR-HOSE COUPLING. NELSON TOY, Weir, Kans.
900,275. FLUID - PRESSURE REGULATOR. LOUIS B. FULTON, Pittsburg, Pa.
900,355. HUMIDIFIER. FRANK B. COMINS, Sharon, Mass.
900,356. HUMIDIFIER. FRANK B. COMINS, Sharon, Mass.
900,418. VARIABLE-CAPACITY COMPRESSOR. BRUNO V. NORDBERG, Milwaukee, Wis.
900,498. PNEUMATIC TIRE. HORACE W. DOVER, Northampton, England.
900,504. WINDMILL. RICHARD G. FINCH, Plainville, Kans.
900,516. APPARATUS FOR MANUFACTURING HYDROGEN GAS. EDMOND GEISENBERGER, Liege, Belgium.
900,533. FLEXIBLE FLUID-JOINT. CHARLES G. HAWLEY, Chicago, Ill.
900,603. FLEXIBLE FLUID-JOINT. EDWARD E. SILK, Chicago, Ill.
900,610. PNEUMATIC PAD. HORTENSIUS E. STOW, Windsor, N. Y.
900,614. VENTILATOR SYSTEM FOR RAILWAY CARRIAGES AND THE LIKE. SERGIUS TIMOCHOWITSCH, Moscow, Russia.
900,632. PUMP FOR PNEUMATIC TIRES. HENRY M. WILLIAMS, Vincennes, Ind.
900,639. AIR-BRAKE SYSTEM. BERT AIKMAN, Chicago, Ill.

OCTOBER 13.

900,752. CONTROLLING MEANS FOR AIR-BRAKES. GEORGE MACLOSKIE, Schenectady, N. Y.
900,812. DENTAL BLOWER. PERCY E. WILLIAMS, Savannah, Ga.
900,814. AIR-COMPRESSOR. WYLIE G. WILSON, Denver, Colo.
900,888. PNEUMATIC TIRE. ARTHUR C. RUDLAND, Vancouver, British Columbia, Canada
900,914. VALVE MECHANISM FOR GLASS-BLOWING APPARATUS. CHARLES M. CLARKE, Pittsburg, Pa.
900,950. TUNNELING-MACHINE. OLIN S. PROCTOR, Denver, Colo.
900,951. TUNNELING-MACHINE. OLIN S. PROCTOR, Denver, Colo.
900,988. PUMPING AND COMPRESSING APPARATUS FOR AERIFORM FLUIDS. HONORE M. DOMECQ-CAZAUX, Paris, France.
901-049. FLUID-PRESSURE DISTRIBUTER. JOSEPH B. TUOR, St. Paul, Minn.
901,068. PNEUMATIC ACTION FOR MUSICAL INSTRUMENTS. JAMES P. CAULFIELD, Baltimore, Md.
901,170. CONTINUOUS-DRAW VACUUM WINDOW-GLASS MACHINE. HARRY D. HERSHEY, Latrobe, Pa.
901,258. ELASTIC-FLUID MOTOR. VICTOR PINGRET, Rio Grande do Sul, Brazil.
901,273. PNEUMATIC ACTION FOR MUSICAL INSTRUMENTS. MORRIS S. WRIGHT, Worcester, Mass.
901,289. COUPLING FOR FLUID-PRESSURE CONDUITS. PETER FURTNER, Rosenheim, Germany.
901,310. METHOD OF SUPPLYING ENERGY TO ENGINES. EDWARD T. YOUNG, Boston, Mass.

2. An improved method of supplying energy to an engine which consists in compressing a body of non-combustible combustion-sustaining gas, preferably atmospheric air, in a chamber to a degree insufficient to ignite the fuel to be used, and heating by external means a sufficient amount of said combustion-sustaining gas to a temperature sufficient to accomplish the ignition of the fuel injected into it, and injecting such fuel into it, whereby said fuel will be ignited and burned, as described.

OCTOBER 20.

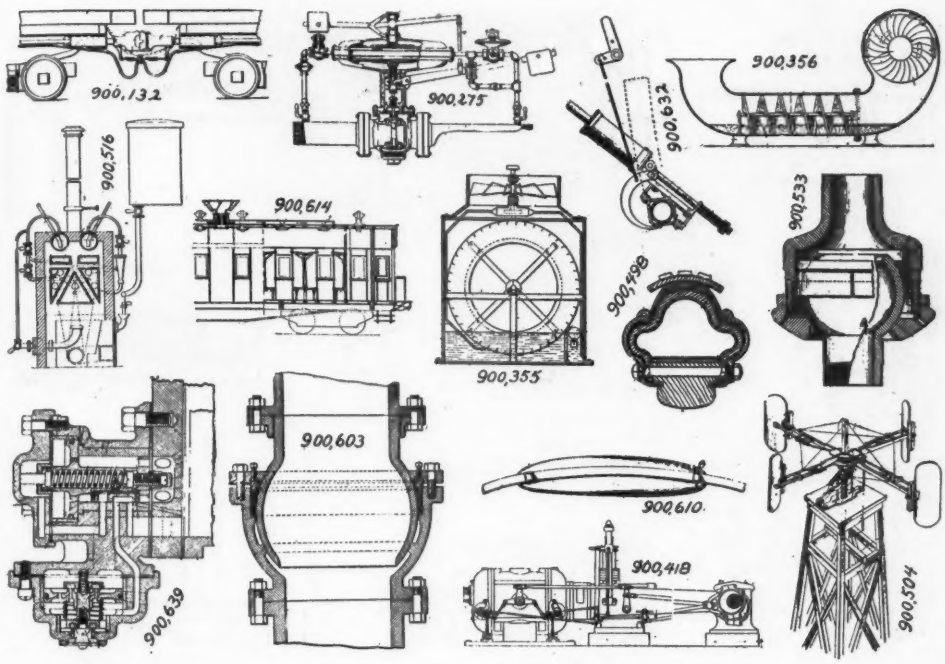
901,344. AIR-COMPRESSOR. HENRY J. HORSTMANN, Fort Wayne, Ind.
901,361. MOLDING PROCESS. WILLIAM F. M. MCCARTY, Pleasantville, N. Y.

1. The hereindescribed process which consists in continuously discharging molten metal, into a hermetically sealed mold, at or near the surface of the metal introduced, until said mold is filled and simultaneously withdrawing air from said mold.

901,392. ROTARY TUNNELING-MACHINE. RUSSEL B. SIGAFOOS, Denver, Colo.
901,490. PNEUMATIC FEEDER FOR THRESHING-MACHINES. CORY W. SELLERS, Beloit, Kan.
901,499. COMBINED MOTOR AND COMPRESSOR. CHARLES P. TOLMAN, New York, N. Y.
901,538. STRIKING-PIN FOR PISTON-HAMMER ROCK-DRILLING ENGINES. JOHN G. LEYNER, Denver, Colo.
901,539. MULTIPLE-STAGE AIR-COMPRESSOR. JOHN G. LEYNER, Denver, Colo.
901,550. FLUID-PRESSURE MOTOR. EBERHARDT P. NICHOLSON, New York, N. Y.
901,555. AIR-COMPRESSOR. THOMAS O. PERRY, Chicago, Ill.
901,580. CONDENSING-APPARATUS PUMP. JOHN ASTROM, Milwaukee, Wis.
901,660. AIR SELF-COUPLING. BENJAMIN F. SWEENEY, Neosho, Mo.
901,741. PRESSURE-REDUCER FOR GASEOUS LIQUIDS. HARRY A. REED, New York, N. Y.
901,923. AIR-BRAKE. JAMES F. MCELROY, Albany, N. Y.

OCTOBER 27.

901,945. AIR-PUMP. PHILLIPS P. BOURNE, Somerville, Mass.
902,001. AUTOMATIC REGULATING DEVICE FOR FLUID-PRESSURE APPARATUS. AUGUSTE C. E. RATEAU, Paris, France.
902,077. DEVICE FOR EXHAUSTING AIR FROM SIPHONS OF SLUICES AND THE LIKE. CHRISTIAN HAVESTADT, Wilmersdorf, near Berlin, Germany.
902,114. FLUID-PRESSURE BRAKE SYSTEM. WILLIAM H. SAUVAGE, New York, N. Y.
902,142. LOG-TURNER. AAGE FOSS and LOREN COOLIDGE, Montesano, Wash.
902,182. HIGH-SPEED-REDUCING VALVE FOR AIR-BRAKES. WALTER V. TURNER, Wilkinsburg, Pa.
902,183. HIGH-SPEED-REDUCING VALVE FOR AIR-BRAKES. WALTER V. TURNER, Wilkinsburg, and JOHN S. CUSTER, Pittsburg,



PNEUMATIC PATENTS, OCTOBER 6.

Pa.

902,184. ELECTROPNEUMATIC BRAKE. WALTER V. TURNER, Wilkinsburg, Pa.

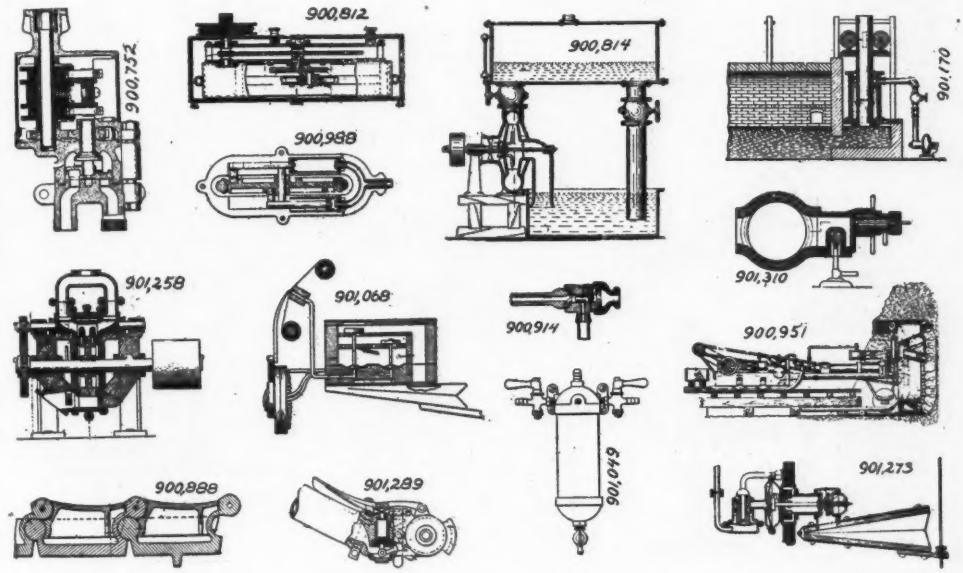
902,264. FLUID-CONTROLLING MEANS. FRED P. STEVENS, Denver, Colo.

902,288. FLUID-PRESSURE-ENGINE-OPERATED TOOL. GEORGE H. GILMAN, Claremont, N. H.

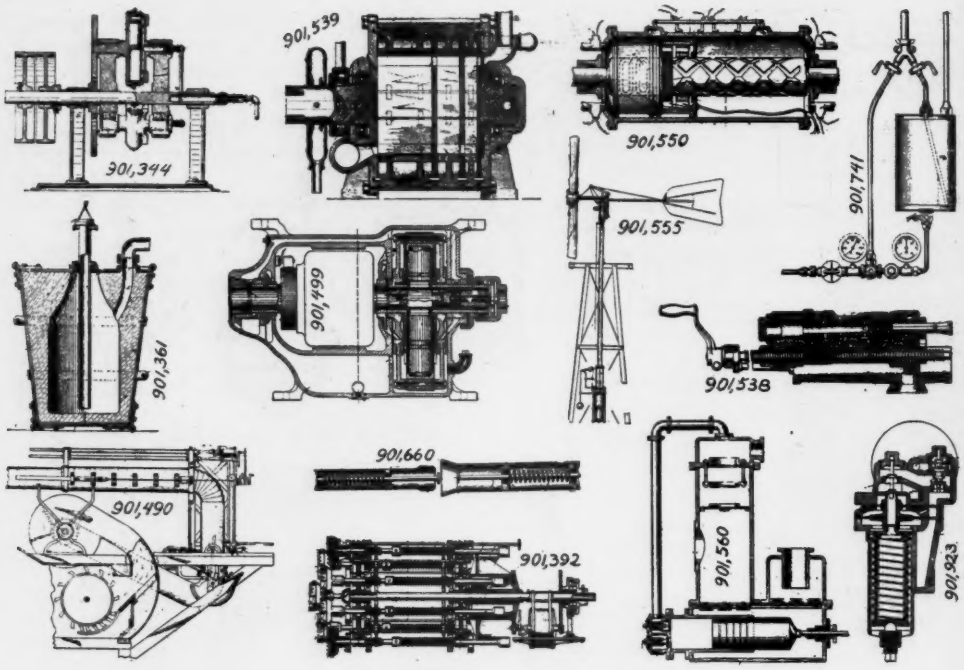
902,382. AUTOPNEUMATIC MOTOR FOR SELF-PLAYING MUSICAL INSTRUMENTS. JOHN W. DARLEY, Jr., Baltimore, Md.

902,441. ROTARY BLOWER OR COMPRESSOR. OSCAR P. OSTERGREN, New York, and CHARLES O. L. CARDELL, Pearl River, N. Y.

902,501. PUMP, &C. FRITZ W. MACHLET, Elizabeth, N. J.

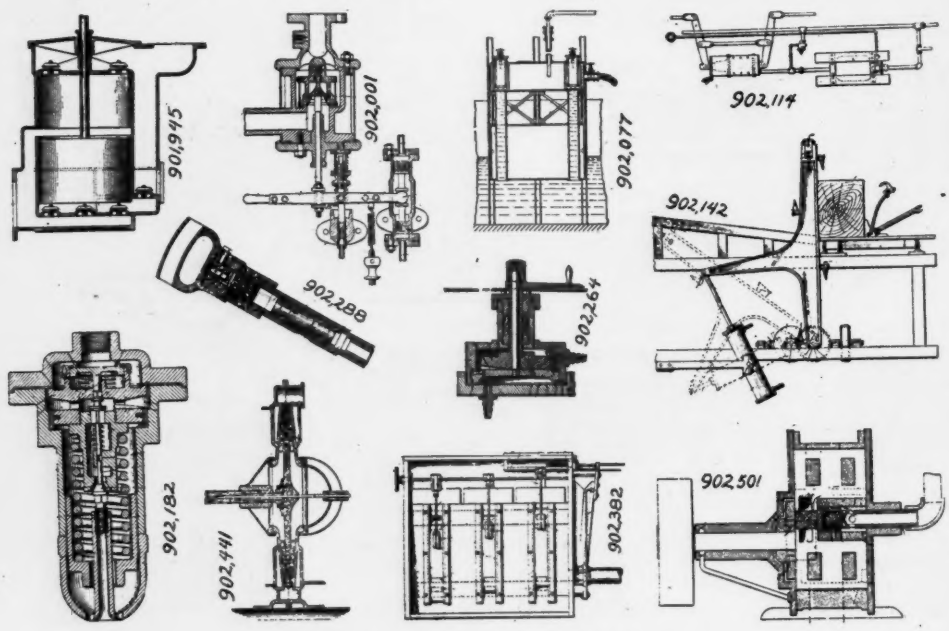


PNEUMATIC PATENTS, OCTOBER 13.



PNEUMATIC PATENTS, OCTOBER 20.

1. A rotary air or gas pump comprising a drum, a hollow cylinder revolving therein, a vane or piston sliding in and out of said cylinder and fitting to the interior of the drum, and means for conducting liquid from the cylinder to the edges of the vane to form a seal or packing for the latter.



PNEUMATIC PATENTS, OCTOBER 27.